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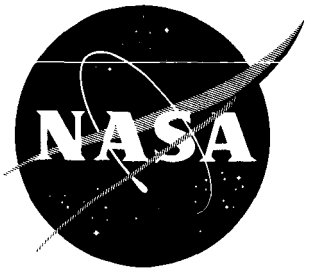

TECHNICAL NOTE

D-714

ANALYSIS OF EFFECTIVE THERMAL CONDUCTIVITIES OF HONEYCOMB-CORE AND CORRUGATED-CORE SANDWICH PANELS

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ANALYSIS OF EFFECTIVE THERMAL CONDUCTIVITIES OF HONEYCOMB-CORE AND CORRUGATED-CORE SANDWICH PANELS

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SUMMARY

Equations are derived for the transfer of heat in sandwich panels. An exact method is developed for considering internal reflections of radiant heat and for reducing the given problem to an equivalent problem which may be solved by well-established black-body methods. Temperature distributions and effective thermal conductivities are calculated for both honeycomb-core and corrugated-core sandwich panels. Equations are derived which give the effective thermal conductivities as functions of the geometric parameters and material properties. A wide range of geometric parameters and material properties is considered.

The case in which the emissivity varies through the panel is studied. It is found that if the average emissivity of the two faces is used, the effective conductivity equation gives satisfactory results except at very low emissivity. The effect of uncertainty in the value of emissivity on the accuracy of calculated thermal conductivities is discussed.

INTRODUCTION

In some of the current and anticipated high-performance flight vehicles sandwich panels are used as an outer skin. Such panels may also find application in the design of space cabins. In thermal studies the quantity of heat transferred through these panels is of importance.

Usually, the thermal resistance of a panel is experimentally determined from measurements of the amount of heat transmitted through a panel in a steady-state condition with fixed face temperatures. (See, for example, ref. 1.) However, the application of experimental results is largely limited to panels which are identical to those tested and to panel temperatures in the same range as the test temperatures. Since it is impractical to obtain extensive test data on the overall thermal

conductivity of all panels of interest, it is desirable to have a means of estimating this property.

Equations for the transfer of heat in sandwich panels, in which reflections of radiant energy from the internal surfaces of the panel are neglected, are developed in reference 2. In reference 3, these equations are modified to permit the calculation of steady-state temperature distributions due to simultaneous conduction and radiation through square-cell honeycomb sandwich panels. The equations are solved for a range of face temperatures, and effective thermal conductivities are presented.

In the present paper, a new method for considering reflections is developed. Net radiation factors which may be calculated from core geometry and surface absorptivity are defined. With the use of these factors, an analysis similar to that of reference 3 is performed. Both honeycomb-core and corrugated-core sandwich panels are considered. Two approximate analytical expressions are obtained, one for each type of panel, which yield effective thermal conductivities that agree with the calculated values with a maximum deviation of 6.5 percent. Calculated effective thermal conductivities are compared with experimental values from reference 3.

SYMBOLS

A	area
ΔA	cross-sectional area of conduction path through core material
$\frac{\rho_c}{\rho}$	solidity, $\frac{\Delta A}{A_1}$
a, b	lengths used in configuration factors
B	integer (See eqs. (20))
C_p	specific heat at constant pressure
d	cell diameter
$f(\lambda, \epsilon)$	function defined by eq. (C3)
$[E]$	matrix defined by eq. (A5)

F	configuration factor
G	net radiation factor
G'	effective net radiation factor
h	heat-transfer coefficient
$\bar{h}$	dimensionless heat-transfer coefficient
i,j,m,n	integers
J	total number of isothermal elements
k	thermal conductivity
l	core height
$l_{m,n}$	distance from the center of element m to the center of element n
$[M]$	general matrix
q	heat per unit area
Q	rate of heat transfer per unit area
$\bar{Q}$	dimensionless rate of heat transfer
$\bar{R}$	function defined by eqs. (20)
S	distance between centers of ΔA_n and ΔA_m
t	thickness
T	temperature
$\bar{T}$	dimensionless temperature
V	volume
$\bar{X}$	thickness-to-height ratio given by eqs. (20), $\left(\frac{\rho_c}{\rho} \sin \phi\right)$

$\bar{Y}$ ratio given by eqs. (20)

z distance from hot face

α absorptivity

δ Kronecker delta

ϵ emissivity

$\bar{\theta}$ dimensionless temperature with no reflections

λ ratio of core height to cell diameter, l/d

ρ density of core material

ρ_c core density

σ Stefan-Boltzmann constant

τ time

ϕ angle of corrugation

ψ angle between normal to ΔA and S

Subscripts:

A air

a ambient

av average

C cold face

c conduction

e effective value

f face

H hot face

i,j,k,m,n integers

r radiant

w web

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ANALYSIS

If an effective thermal conductivity which includes the effects of all modes of heat transfer can be determined for a sandwich panel whose faces are at different constant temperatures, the amount of heat that is transmitted through the panel can be calculated. Since air spaces normally exist in such panels, it is necessary to consider radiation between surfaces and convection and conduction through the air as well as conduction through the walls of the cells.

The determination of the effective thermal conductivity is complicated by the fact that, in general, the heat transferred by any mode is a nonlinear function of temperature and all modes of heat transfer are interrelated. However, the amount of heat transferred by the air is usually small, and the heat transmitted by other modes can be considered independently of it. In most cases, the structural members of the panels are made of very thin sheets. Because of this fact the temperature drop through these sheets is very small and the thermal resistance through the sheets can be neglected; thus a one-dimensional analysis is possible. With these simplifications, the equations for the transfer of heat by radiation and conduction through sandwich panels can be derived by using a finite-difference procedure similar to that used in reference 2.

Let the given configuration be divided into a system of J elements, each of which will be considered isothermal. The heat conducted from element $m - 1$ to element m is

$$A_{m,m-1}k_{m,m-1}\frac{\left(T_{m-1} - T_m\right)\Delta\tau}{l_{m,m-1}}$$

where $A_{m,m-1}$ is the average area of the conduction path, $k_{m,m-1}$ is the average thermal conductivity, and $l_{m,m-1}$ is the distance between the centers of the elements. The heat conducted from element $m + 1$ to element m is

$$A_{m,m+1}k_{m,m+1}\frac{\left(T_{m+1} - T_m\right)\Delta\tau}{l_{m,m+1}}$$

In appendix A the radiant energy is traced through all reflections which occur and it is shown that, for gray-body radiation, the net radiant-heat input to element m is

$$\sigma \sum_{k=1}^{J} A_k \epsilon_k \left(G_{k,m} - \delta_{k,m}\right) T_k^4 \Delta\tau$$

where G is the net radiation factor and δ is the Kronecker delta. Net radiation factors are a function of the absorptivities of the surfaces and the configuration factors discussed in appendix B. In addition, there may be a heat input from a fluid at temperature $T_{a,m}$,

$$A_m k_m (T_{a,m} - T_m) \Delta\tau$$

and/or a heat input of specific magnitude,

$$A_m Q_m \Delta\tau$$

The net heat input to element m is equal to the sum of these quantities as follows:

$$\Delta q_m = \left[A_m Q_m + A_m k_m (T_{a,m} - T_m) + A_{m,m+1} k_{m,m+1} \frac{(T_{m+1} - T_m)}{l_{m,m+1}} + A_{m,m-1} k_{m,m-1} \frac{(T_{m-1} - T_m)}{l_{m,m-1}} + \sigma \sum_{k=1}^{J} A_k \epsilon_k (G_{k,m} - \delta_{k,m}) T_k^4 \right] \Delta\tau \qquad (1)$$

This heat input will cause a temperature rise ΔT_m given by the relationship:

$$\Delta q_m = \rho_m V_m C_{p,m} \Delta T_m \qquad (2)$$

where V_m is the volume of element m.

Equating equations (1) and (2) and taking the limit as $\Delta\tau \to 0$ yields a general relation for the element m

$$\rho_m V_m C_{p,m} \frac{dT_m}{d\tau} = A_m Q_m + A_m k_m (T_{a,m} - T_m) + A_{m,m+1} k_{m,m+1} \frac{(T_{m+1} - T_m)}{l_{m,m+1}} + A_{m,m-1} k_{m,m-1} \frac{(T_{m-1} - T_m)}{l_{m,m-1}} + \sigma \sum_{k=1}^{J} A_k \epsilon_k (G_{k,m} - \delta_{k,m}) T_k^4 \qquad (3)$$

In the steady-state condition considered here, $\frac{dT_m}{d\tau} = 0$ and the equations governing the temperature distribution are, with $m = 1, 2, \ldots J$,

$$A_m Q_m + A_m k_m (T_{a,m} - T_m) + A_{m,m+1} k_{m,m+1} \frac{(T_{m+1} - T_m)}{l_{m,m+1}}$$

$$+ A_{m,m-1} k_{m,m-1} \frac{(T_{m-1} - T_m)}{l_{m,m-1}} + \sigma \sum_{k=1}^{J} A_k \epsilon_k (G_{k,m} - \delta_{k,m}) T_k^4 = 0 \qquad (4)$$

Application of equations (4) to the honeycomb-core panel and to the corrugated-core panel will now be considered.

Honeycomb-Core Panels

In the analysis which follows, it is assumed that the thermal conductivity is constant at a value corresponding to the mean temperature of the panel. It is also assumed that there are no temperature gradients in the planes of the faces and that the cells of the honeycomb are right circular cylinders. Each cylinder is divided into 10 elements (fig. 1) and each element has a height of $l/10$. The lengths on which equations (4) are based are taken between the centers of the elements. The faces are elements 1 and 12, and it is assumed that the temperatures of these face elements are known; therefore, no heat-balance equations are necessary for elements 1 and 12. In the core, there are no convective heat inputs and no arbitrarily specified heat inputs; therefore, for $m \neq 1, 12$,

$$h_m = Q_m = 0 \qquad (5)$$

From figure 1, for $m = 2, 3, \ldots 11$,

$$\left.\begin{aligned} l_{1,2} &= \frac{l}{20} \\ l_{m,m+1} &= \frac{l}{10} \\ l_{11,12} &= \frac{l}{20} \end{aligned}\right\} \qquad (6)$$

Therefore, for the honeycomb-core panel, equations (4) become, for element 2,

$$10\,\frac{k\,\Delta A}{l}\left(2T_1 - 3T_2 + T_3\right) + \sigma \sum_{k=1}^{12} A_k \epsilon_k \left(G_{k,2} - \delta_{k,2}\right) T_k^{\,4} = 0 \qquad (7a)$$

for elements 3 to 10,

$$10\,\frac{k\,\Delta A}{l}\left(T_{m-1} - 2T_m + T_{m+1}\right) + \sigma \sum_{k=1}^{12} A_k \epsilon_k \left(G_{k,m} - \delta_{k,m}\right) T_k^{\,4} = 0 \qquad (7b)$$

and for element 11,

$$10\,\frac{k\,\Delta A}{l}\left(T_{10} - 3T_{11} + 2T_{12}\right) + \sigma \sum_{k=1}^{12} A_k \epsilon_k \left(G_{k,11} - \delta_{k,11}\right) T_k^{\,4} = 0 \qquad (7c)$$

If a dimensionless temperature

$$\overline{T}_m = \left(\frac{\sigma l A_1}{k\,\Delta A}\right)^{1/3} T_m \qquad (8)$$

is defined and substituted into equations (7), these equations can be reduced to the form

$$\left.\begin{aligned}
&10\left(2\overline{T}_1 - 3\overline{T}_2 + \overline{T}_3\right) + \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k \left(G_{k,2} - \delta_{k,2}\right) \overline{T}_k^{\,4} = 0 \\
&10\left(\overline{T}_{m-1} - 2\overline{T}_m + \overline{T}_{m+1}\right) + \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k \left(G_{k,m} - \delta_{k,m}\right) \overline{T}_k^{\,4} = 0 \\
&\qquad\qquad (m = 3,\ 4,\ 5,\ \ldots\ 10) \\
&10\left(\overline{T}_{10} - 3\overline{T}_{11} + 2\overline{T}_{12}\right) + \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k \left(G_{k,11} - \delta_{k,11}\right) \overline{T}_k^{\,4} = 0
\end{aligned}\right\} \qquad (9)$$

Therefore, if $\overline{T}_1$, $\overline{T}_{12}$, the ratio of core height to cell diameter $\frac{l}{d} = \lambda$, and the emissivities are given, equations (9) may be solved for the temperature distribution through the panel.

In order to maintain a steady-state temperature distribution, the amount of heat removed at the cold face (element 12) must be balanced by an equal amount of heat supplied at the hot face (element 1). The net flux of heat from the core and the hot face to the cold face Q_{12} is given by the equation

$$A_{12}Q_{12} = 20\,\frac{k\,\Delta A}{l}\left(T_{11} - T_{12}\right) + \sigma \sum_{k=1}^{12} A_k \epsilon_k \left(G_{k,12} - \delta_{k,12}\right) T_k^{\,4} \qquad (10)$$

After substitution of $\overline{T}$ for T and A_1 for A_{12}, equation (10) becomes

$$Q_{12} = \left(\frac{k\,\Delta A}{\sigma l A_1}\right)^{1/3} \frac{k\,\Delta A}{l A_1}\left[20\left(\overline{T}_{11} - \overline{T}_{12}\right) + \sum_{k=1}^{12} \frac{A_k}{A_1}\,\epsilon_k \left(G_{k,12} - \delta_{k,12}\right) \overline{T}_k^{\,4}\right] \qquad (11)$$

An effective thermal conductivity k_e is now defined so that

$$Q_{12} = \frac{k_e}{l}\left(T_1 - T_{12}\right) \qquad (12)$$

Substitution of the dimensionless temperature in this equation yields

$$Q_{12} = \left(\frac{k\,\Delta A}{\sigma l A_1}\right)^{1/3} \frac{k_e}{l}\left(\overline{T}_1 - \overline{T}_{12}\right) \qquad (13)$$

Eliminating Q_{12} from equations (11) and (13) gives

$$\frac{k_e A_1}{k\,\Delta A}\left(\overline{T}_1 - \overline{T}_{12}\right) = 20\left(\overline{T}_{11} - \overline{T}_{12}\right) + \sum_{k=1}^{12} \frac{A_k}{A_1}\,\epsilon_k \left(G_{k,12} - \delta_{k,12}\right) \overline{T}_k^{\,4} \qquad (14)$$

The effective thermal conductivity given by equation (12) does not include any effects of air. A first approximation to the effect of air can be obtained by considering only conduction through the air. (See ref. 3.) In this approximation, the heat transmitted by the air is

$$Q_A = \frac{k_A(T_1 - T_{12})}{l} \tag{15}$$

Values of k_A, the thermal conductivity of air, are given on page 70 of reference 4.

Finally, the overall thermal conductivity is defined as

$$k = k_e + k_A \tag{16}$$

Corrugated-Core Panels

The analysis of corrugated-core panels is not as straightforward as that of honeycomb-core panels. The faces are not isothermal because the corrugation is in contact with the faces only at relatively large intervals, and the thickness of the corrugation is of the same order of magnitude as the face thickness.

Although it is still possible to define an effective thermal conductivity based on the average temperatures of the faces, it is necessary to specify the method by which heat is applied and removed from the panel in order to calculate the temperatures of the face elements.

In this analysis it is assumed that heat is added to one face at a constant rate, and at the other face heat is removed by convection to a fluid with constant ambient temperature. A constant heat-transfer coefficient between the fluid and the adjacent face is assumed. By specifying the average temperatures of the faces, sufficient equations are available to determine the temperatures of the elements, the heating rate, and the temperature of the fluid.

Another difficulty in the analysis of corrugated panels is the effect of radiation along the passages. In this analysis, end effects are neglected; that is, the passages are assumed to be infinitely long or to be blocked by reflecting surfaces. Because of this assumption, the location along the passage at which the analysis is made is not important and a unit dimension in this direction is used.

The cross section of the panel is divided into 12 elements, as shown in figure 2. From the figure

$$\left.\begin{aligned} l_{1,2} &= l_{2,3} = l_{10,11} = l_{11,12} = \frac{2}{5}\, l \cot \phi \\ l_{3,4} &= l_{9,10} = \frac{1}{5}\, l \cot \phi + \frac{t_w}{2 \sin \phi} \\ l_{4,5} &= l_{8,9} = \frac{l}{8 \sin \phi} \\ l_{5,6} &= l_{6,7} = l_{7,8} = \frac{l}{4 \sin \phi} \end{aligned}\right\} \tag{17}$$

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Heat transfer by radiation takes place in the triangular passageways. Only one-half of each triangle shown need be included in the cross section considered. The temperatures of the elements in the triangles visible to the cross section but not included in the cross section can be found by symmetry; for example, elements 6 and 6a have the same temperature. The contribution of triangle elements outside the cross section to radiant heat transfer through the cross section is obtained by using effective net radiation factors designated by G'. For example,

$$G'_{6,1} = G_{6,1} + G_{6a,1} \tag{18}$$

Equations (4) yield the following system of equations for the temperatures in the corrugated-core panel:

$$\left.\begin{aligned} & Q \frac{l \cot \phi}{5} - \frac{k_f t_f (T_1 - T_2)}{\frac{2l \cot \phi}{5}} + \frac{l\sigma}{5} \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k (G'_{k,1} - \delta_{k,1}) T_k^4 = 0 \\ & Q \frac{2l \cot \phi}{5} + \frac{k_f t_f (T_1 - 2T_2 + T_3)}{\frac{2l \cot \phi}{5}} + \frac{l\sigma}{5} \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k (G'_{k,2} - \delta_{k,2}) T_k^4 = 0 \\ & Q \frac{2l \cot \phi}{5} + \frac{k_f t_f (T_2 - T_3)}{\frac{2l \cot \phi}{5}} - \frac{k_f t_f (T_3 - T_4)}{\frac{l \cot \phi}{5} + \frac{t_w}{2 \sin \phi}} + \frac{l\sigma}{5} \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k (G'_{k,3} - \delta_{k,3}) T_k^4 = 0 \end{aligned}\right\} \tag{19}$$

(Equations continued on next page)

$$
\left.
\begin{aligned}
&Q\frac{t_w}{\sin\phi} + \frac{k_f t_f (T_3 - T_4)}{\frac{l\cot\phi}{5} + \frac{t_w}{2\sin\phi}} - \frac{k_w t_w (T_4 - T_5)}{\frac{l}{8\sin\phi}} = 0 \\
&\frac{k_w t_w (T_4 - T_5)}{\frac{l}{8\sin\phi}} - \frac{k_w t_w (T_5 - T_6)}{\frac{l}{4\sin\phi}} + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,5} - 2\delta_{k,5})T_k^4 = 0 \\
&\frac{k_w t_w}{\frac{l}{4\sin\phi}}(T_5 - 2T_6 + T_7) + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,6} - 2\delta_{k,6})T_k^4 = 0 \\
&\frac{k_w t_w}{\frac{l}{4\sin\phi}}(T_6 - 2T_7 + T_8) + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,7} - 2\delta_{k,7})T_k^4 = 0 \\
&\frac{k_w t_w (T_7 - T_8)}{\frac{l}{4\sin\phi}} - \frac{k_w t_w (T_8 - T_9)}{\frac{l}{8\sin\phi}} + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,8} - 2\delta_{k,8})T_k^4 = 0 \\
&\frac{k_w t_w (T_8 - T_9)}{\frac{l}{8\sin\phi}} - \frac{k_f t_f (T_9 - T_{10})}{\frac{l\cot\phi}{5} + \frac{t_w}{2\sin\phi}} - \frac{t_w}{\sin\phi}h(T_9 - T_a) = 0 \\
&\frac{k_f t_f (T_9 - T_{10})}{\frac{l\cot\phi}{5} + \frac{t_w}{2\sin\phi}} - \frac{k_f t_f (T_{10} - T_{11})}{\frac{2l\cot\phi}{5}} - \frac{2l\cot\phi}{5}h(T_{10} - T_a) + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,10} - \delta_{k,10})T_k^4 = 0 \\
&\frac{k_f t_f (T_{10} - 2T_{11} + T_{12})}{\frac{2l\cot\phi}{5}} - \frac{2l\cot\phi}{5}h(T_{11} - T_a) + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,11} - \delta_{k,11})T_k^4 = 0 \\
&\frac{k_f t_f (T_{11} - T_{12})}{\frac{2l\cot\phi}{5}} - \frac{l\cot\phi}{5}h(T_{12} - T_a) + \frac{l\sigma}{5}\sum_{k=1}^{12}\frac{A_k}{A_1}\epsilon_k (G'_{k,12} - \delta_{k,12})T_k^4 = 0
\end{aligned}
\right\} \qquad (19)
$$

If the following substitutions are made,

$$\left.\begin{aligned}
&\bar{T}_m = \left(\frac{\sigma l^2}{k_f t_f}\right)^{1/3} T_m \\
&\bar{X} = \frac{t_w}{l}; \qquad \frac{\bar{X}}{\sin\phi} = \frac{t_w l}{l^2 \sin\phi} = \text{Solidity} \\
&\bar{Y} = \frac{k_w t_w}{k_f t_f}; \qquad \bar{Q} = \frac{Q l^2}{k_f t_f}\left(\frac{\sigma l^2}{k_f t_f}\right)^{1/3}; \qquad \bar{h} = \frac{h l^2}{k_f t_f} \\
&\bar{R}_m = \sum_{k=1}^{12} \frac{A_k}{A_1} \epsilon_k \left(G'_{k,m} - B_m \delta_{k,m}\right) \bar{T}_k^{\,4} \\
&(B = 1 \text{ for } m = 1, 2, 3, 10, 11, 12;\ B = 2 \text{ for } m = 5, 6, 7, 8)
\end{aligned}\right\} \qquad (20)$$

and ϕ is specified as 45°, equations (19) become

$$\left.\begin{aligned}
&\bar{Q} - \frac{25}{2}\left(\bar{T}_1 - \bar{T}_2\right) + \bar{R}_1 = 0 \\
&2\bar{Q} + \frac{25}{2}\left(\bar{T}_1 - \bar{T}_2\right) - \frac{25}{2}\left(\bar{T}_2 - \bar{T}_3\right) + \bar{R}_2 = 0 \\
&2\bar{Q} + \frac{25}{2}\left(\bar{T}_2 - \bar{T}_3\right) - \frac{25\sqrt{2}}{\sqrt{2} + 5\bar{X}}\left(\bar{T}_3 - \bar{T}_4\right) + \bar{R}_3 = 0 \\
&5\sqrt{2\bar{X}\bar{Q}} + \frac{25\sqrt{2}}{\sqrt{2} + 5\bar{X}}\left(\bar{T}_3 - \bar{T}_4\right) - 20\sqrt{2\bar{Y}}\left(\bar{T}_4 - \bar{T}_5\right) = 0 \\
&4\sqrt{2\bar{Y}}\left(\bar{T}_4 - \bar{T}_5\right) - 2\sqrt{2\bar{Y}}\left(\bar{T}_5 - \bar{T}_6\right) + \frac{1}{5}\bar{R}_5 = 0 \\
&2\sqrt{2\bar{Y}}\left(\bar{T}_5 - \bar{T}_6\right) - 2\sqrt{2\bar{Y}}\left(\bar{T}_6 - \bar{T}_7\right) + \frac{1}{5}\bar{R}_6 = 0
\end{aligned}\right\} \qquad (21)$$

(Equations continued on next page)

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\begin{aligned}
&2\sqrt{2\bar{Y}}\left(\bar{T}_6 - \bar{T}_7\right) - 2\sqrt{2\bar{Y}}\left(\bar{T}_7 - \bar{T}_8\right) + \frac{1}{5}\bar{R}_7 = 0 \\
&2\sqrt{2\bar{Y}}\left(\bar{T}_7 - \bar{T}_8\right) - 4\sqrt{2\bar{Y}}\left(\bar{T}_8 - \bar{T}_9\right) + \frac{1}{5}\bar{R}_8 = 0 \\
&4\sqrt{2\bar{Y}}\left(\bar{T}_8 - \bar{T}_9\right) - \frac{5\sqrt{2}}{\sqrt{2} + 5\bar{X}}\left(\bar{T}_9 - \bar{T}_{10}\right) - \sqrt{2\bar{X}\bar{h}}\left(\bar{T}_9 - \bar{T}_a\right) = 0 \\
&\frac{25\sqrt{2}}{\sqrt{2} + 5\bar{X}}\left(\bar{T}_9 - \bar{T}_{10}\right) - \frac{25}{2}\left(\bar{T}_{10} - \bar{T}_{11}\right) - 2\bar{h}\left(\bar{T}_{10} - \bar{T}_a\right) + \bar{R}_{10} = 0 \\
&\frac{25}{2}\left(\bar{T}_{10} - \bar{T}_{11}\right) - \frac{25}{2}\left(\bar{T}_{11} - \bar{T}_{12}\right) - 2\bar{h}\left(\bar{T}_{11} - \bar{T}_a\right) + \bar{R}_{11} = 0 \\
&\frac{25}{2}\left(\bar{T}_{11} - \bar{T}_{12}\right) - \bar{h}\left(\bar{T}_{12} - \bar{T}_a\right) + \bar{R}_{12} = 0
\end{aligned}
\right\} \qquad (21)
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The average temperature of the hot face is

$$
T_{H,av} = \frac{\frac{l \cot \phi}{5} T_1 + \frac{2l \cot \phi}{5} T_2 + \frac{2l \cot \phi}{5} T_3 + \frac{t_w}{\sin \phi} T_4}{l \cot \phi + \frac{t_w}{\sin \phi}} \qquad (22)
$$

and the average temperature of the cold face is

$$
T_{C,av} = \frac{\frac{l \cot \phi}{5} T_{12} + \frac{2l \cot \phi}{5} T_{11} + \frac{2l \cot \phi}{5} T_{10} + \frac{t_w}{\sin \phi} T_9}{l \cot \phi + \frac{t_w}{\sin \phi}} \qquad (23)
$$

By using equations (20), equations (22) and (23) become

$$
\bar{T}_{H,av} = \frac{\bar{T}_1 + 2\bar{T}_2 + 2\bar{T}_3 + 5\sqrt{2\bar{X}\bar{T}_4}}{5 + 5\sqrt{2\bar{X}}} \qquad (24)
$$

$$\bar{T}_{C,av} = \frac{\bar{T}_{12} + 2\bar{T}_{11} + 2\bar{T}_{10} + 5\sqrt{2\bar{X}\bar{T}_9}}{5 + 5\sqrt{2\bar{X}}} \tag{25}$$

The effective thermal conductivity of the panel is defined by the following equation:

$$Q = \frac{k_e}{l}\left(T_{H,av} - T_{C,av}\right) \tag{26}$$

where Q is the overall heat flow through the panel and k_e is the effective thermal conductivity of the panel. Substitution of the dimensionless temperature of equation (20) yields

$$Q = \left(\frac{k_f t_f}{\sigma l^2}\right)^{1/3} \frac{k_e}{l}\left(\bar{T}_{H,av} - \bar{T}_{C,av}\right) \tag{27}$$

By placing this overall heat flow equal to the heat input to the upper face and by making the substitutions of equations (20), the dimensionless heat flow can be expressed as follows:

$$\bar{Q} = \frac{k_e}{k_w \bar{X}} \bar{Y}\left(\bar{T}_{H,av} - \bar{T}_{C,av}\right) \tag{28}$$

Solution of equations (21), (24), and (25) for specified values of $\bar{T}_{H,av}$, $\bar{T}_{C,av}$, $\bar{X}$, $\bar{Y}$, and $\bar{h}$ gives the temperatures of the 12 elements, $\bar{Q}$ and $\bar{T}_a$. With these values, equation (28) can be solved for the effective conductivity ratio $\frac{k_e}{k_w \bar{X}}$.

RESULTS

Honeycomb-Core Panels

Typical calculated temperature distributions through the honeycomb-core panel are presented in figure 3. The extreme values of λ and ϵ were used in this figure; therefore, it may be anticipated that other distributions would lie within the band formed by these curves. The gradient at the cold face ($z/l = 1$) is greater than that resulting from a linear temperature distribution through the panel, and consequently a greater amount of heat is transmitted to the cold face by conduction

when radiation is considered. The thickness of the temperature distribution band decreases as the temperature level of the panel decreases, and as the temperature difference $\left(\overline{T}_1 - \overline{T}_{12}\right)$ decreases.

A tabulation of the calculated values of $\frac{k_e A_1}{k\,\Delta A}$ for honeycomb-core panels having constant emissivity (assumed to be equal to absorptivity) is presented in table I. Values of the ratio of core height to cell diameter, λ, between 1 and 10 and emissivities between 0.2 and 1.0 were used. The corresponding net radiation factors are given in table II.

Solutions were also obtained for some cases in which the emissivity was the same for both faces but different from the emissivity of the core. The values of $\frac{k_e A_1}{k\,\Delta A}$ for these cases are given in table III. A few solutions were obtained for cases in which the emissivities of the faces differ. The results of these calculations are summarized in the section entitled "Discussion."

Corrugated-Core Panels

Typical calculated temperature distributions through the cross section of the corrugated-core panel are shown in figure 4. Since the temperature distribution is essentially independent of $\overline{Y}\left(=\frac{k_w t_w}{k_f t_f}\right)$ only curves for $\overline{Y} = 0.5$ are shown. It can be seen that high emissivity values produce a large variation in the temperature levels of the two faces with the greatest variation occurring at the elements which do not experience radiant heat transfer. There is also some variation in the temperature levels of these elements as $\overline{X}\left(=\frac{t_w}{l}\right)$ varies, with the higher temperatures corresponding to the larger value of $\overline{X}$. Since curves for the extreme cases are shown, all other curves lie within this band.

A tabulation of the calculated values of $\frac{k_e}{k_w \overline{X}}$ for the corrugated-core panel is given in table IV. A constant emissivity (assumed to be equal to absorptivity) through the panel was used over an emissivity range from 0.2 to 1.0. Values of the $\overline{X}$ parameter used were 0.1, 0.05, and 0.02; the parameter $\overline{Y}$ was given the values 0.75, 0.50, and 0.25.

The net radiation factors for the elements (fig. 2), which in this analysis vary only with absorptivity, are given in table V.

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Application of Results

The primary purpose of determining an effective thermal conductivity for a sandwich panel is to make possible the calculation of the heat transmitted through the panel. The effective thermal conductivities calculated herein can be used to find the amount of heat transmitted through honeycomb-core and corrugated-core panels under steady-state conditions by use of equations (13) and (21), respectively. In appendix C approximate equations are derived in which the effective conductivity is expressed in terms of material properties and panel geometry. These equations are, for the honeycomb-core panel (eq. (C4))

$$\frac{k_e A_1}{k\,\Delta A} = 1 + 0.664(\lambda + 0.3)^{-0.69}\epsilon^{1.63(\lambda+1)^{-0.89}}\left(\bar{T}_1^{\,2} + \bar{T}_{12}^{\,2}\right)\left(\bar{T}_1 + \bar{T}_{12}\right)$$

and for the corrugated-core panel (eq. (C9)),

$$\frac{k_e}{k_w \bar{X}} = \frac{k_{e,c}}{k_w \bar{X}} + 0.298\,\frac{(\bar{X})^{-0.045}}{\bar{Y}}(\epsilon + 0.21)^{1.8}\left(\bar{T}_{H,av}^{\,2} + \bar{T}_{C,av}^{\,2}\right)\left(\bar{T}_{H,av} + \bar{T}_{C,av}\right)$$

Equations for the heat transmitted through the panels, based on these two expressions, will now be determined.

Honeycomb-core panels.- The equation for heat transfer through the honeycomb-core panel is found by introducing equation (8) into equations (C2) and (C4) to get the effective conductivity in terms of real temperature and then by substituting the resulting equation into equation (13). The effect of conduction through the air in the cell, equation (15), must also be included. The resulting equation is:

$$Q = \frac{k\,\Delta A}{l A_1}\left(T_1 - T_{12}\right) + \frac{k_A}{l}\left(T_1 - T_{12}\right) + f(\lambda,\epsilon)\sigma\left(T_1^{\,4} - T_{12}^{\,4}\right)$$

$$= \frac{k\,\Delta A}{l A_1}\left(T_1 - T_{12}\right) + \frac{k_A}{l}\left(T_1 - T_{12}\right)$$

$$+ \left[0.664(\lambda + 0.3)^{-0.69}\epsilon^{1.63(\lambda+1)^{-0.89}}\sigma\left(T_1^{\,4} - T_{12}^{\,4}\right)\right] \qquad (29)$$

In this equation $f(\lambda,\epsilon)$ has the significance of an effective emissivity.

Corrugated-core panels.- By using the same procedure as that for the honeycomb-core panel, the temperature expression $\overline{T}_m = \left(\frac{\sigma l^2}{k_f t_f}\right)^{1/3} T_m$ is introduced into equation (C9), the result substituted into equation (27), and the appropriate air-conduction term added. The resulting equation is

$$Q = \frac{k_{e,c}}{l}\left(T_{H,av} - T_{C,av}\right) + \frac{k_A}{l}\left(T_{H,av} - T_{C,av}\right) + 0.298\left(\overline{X}\right)^{-0.045}(\epsilon + 0.21)^{1.8}\sigma\left(T_{H,av}^4 - T_{C,av}^4\right) \qquad (30)$$

where $k_{e,c}$ is given by equation (C7).

DISCUSSION

Effects of Cell Geometry and Surface Properties on Effective Conductivity

Honeycomb-core panels.- The quantity $\frac{k_e A_l}{k\,\Delta A} - 1$ is a direct measure of the importance of radiation on heat-transfer transmission through the panel. It may be interpreted physically as follows:

$$\frac{k_e A_l}{k\,\Delta A} - 1 = \frac{\text{(Heat transmitted with radiation) - (Heat transmitted with no radiation)}}{\text{(Heat transmitted with no radiation)}} \qquad (31)$$

This quantity is shown in appendix C to be approximately proportional to $\left(\overline{T}_1^2 + \overline{T}_{12}^2\right)\left(\overline{T}_1 + \overline{T}_{12}\right)$. The factor of proportionality depends on λ and ϵ (fig. 5). The magnitude of the ordinate in figure 5 is an indication of the importance of radiation. An increase in λ or a decrease in ϵ decreases the effect of radiation. The largest radiation effect occurs with small values of λ and large values of ϵ. For large values of λ and small emissivities, the radiation effect will seldom exceed the conduction effect for metallic sandwiches.

Corrugated-core panels.- The radiation parameter $\frac{k_e}{k_w \overline{X}} - \frac{k_{e,c}}{k_w \overline{X}}$ differs from that used for honeycomb-core panels in that it has not been

divided by the quantity (Heat transmitted with no radiation). The important parameters which influence the conductivity are found to be $\bar{Y}$ and ϵ; the effect of $\bar{X}$ is slight. In figure 6 it is seen that, for large values of ϵ and small values of $\bar{Y}$, the effect of radiation is large. Decreasing ϵ or increasing $\bar{Y}$ decreases the effect of radiation on the effective conductivity. Although the preceding remarks apply to the effective conductivity, the radiation term in the heat-transfer equation (eq. (30)) is dependent primarily on the emissivity.

Effect of Reflections

A simplifying procedure commonly used in the analysis of heat transfer through sandwich panels is to assume that the absorptivity of the internal surfaces is 1 (e.g., ref. 3). It will now be shown that this assumption can lead to serious errors. It is possible to determine the effective conductivity predicted by such an analysis by using the solutions from the present analysis. By comparing the effective conductivity for $\alpha = 1$ with the effective conductivity for $\alpha = \epsilon$, the conditions for which it is necessary to consider the reflections can be indicated.

If the absorptivity is unity, the configuration factors and the net radiation factors are equal. That is,

$$F_{k,m} = G_{k,m} \qquad (\alpha = 1) \tag{32}$$

Now the substitution

$$\bar{\theta}_m = \epsilon^{1/3}\bar{T}_m \tag{33}$$

is made in equations (9). The emissivity is assumed to be constant. Then equations (9) become:

$$\left.\begin{aligned}
&10\left(2\bar{\theta}_1 - 3\bar{\theta}_2 + \bar{\theta}_3\right) + \sum_{k=1}^{12} \frac{A_k}{A_1}\left(F_{k,2} - \delta_{k,2}\right)\bar{\theta}_k^{\,4} = 0 \\
&10\left(\bar{\theta}_{m-1} - 2\bar{\theta}_m + \bar{\theta}_{m+1}\right) + \sum_{k=1}^{12} \frac{A_k}{A_1}\left(F_{k,m} - \delta_{k,m}\right)\bar{\theta}_k^{\,4} = 0 \\
&\qquad\qquad (m = 3,\ 4,\ 5,\ \ldots\ 10) \\
&10\left(\bar{\theta}_{10} - 3\bar{\theta}_{11} + 2\bar{\theta}_{12}\right) + \sum_{k=1}^{12} \frac{A_k}{A_1}\left(F_{k,11} - \delta_{k,11}\right)\bar{\theta}_k^{\,4} = 0
\end{aligned}\right\} \tag{34}$$

If $\epsilon = \alpha = 1$, equations (9) and equations (34) are mathematically identical. Therefore, if reflections are not considered, the effective conductivity is

$$\left(\frac{k_e A_1}{k\ \Delta A} - 1\right)_{\alpha=1} = f(\lambda,1)\left(\bar{\theta}_1^{\,2} + \bar{\theta}_{12}^{\,2}\right)\left(\bar{\theta}_1 + \bar{\theta}_{12}\right) \tag{35}$$

Substitution for $\bar{\theta}$ from equation (33) yields

$$\left(\frac{k_e A_1}{k\ \Delta A} - 1\right)_{\alpha=1} = \epsilon f(\lambda,1)\left(\bar{T}_1^{\,2} + \bar{T}_{12}^{\,2}\right)\left(\bar{T}_1 + \bar{T}_{12}\right) \tag{36}$$

(Note that in eq. (36) ϵ is not restricted to the condition $\epsilon = 1$.) The ratio of $\frac{k_e A_1}{k\ \Delta A} - 1$ with no reflections ($\alpha = 1$) to $\frac{k_e A_1}{k\ \Delta A} - 1$ with reflections ($\alpha = \epsilon$) is

$$\frac{\left(\frac{k_e A_1}{k\ \Delta A} - 1\right)_{\alpha=1}}{\left(\frac{k_e A_1}{k\ \Delta A} - 1\right)_{\alpha=\epsilon}} = \epsilon^{1-1.63(\lambda+1)^{-0.89}} \tag{37}$$

Equation (37) is plotted in figure 7 for various values of λ. The curves show that for high emissivity values or for λ values of about 0.73 the two analyses give comparable results. For values of λ less than 0.73 the no-reflection analysis overestimates the heat transfer through the panel, whereas for values of λ greater than 0.73 the no-reflection analysis underestimates the heat transfer. Most actual honeycomb panels have a ratio of core height to cell diameter greater than 1. Therefore at low emissivities the no-reflection analysis may predict heat flows which are one-third the actual heat flow.

Effects of Variable Emissivity

A number of cases were solved to investigate the effects of variable emissivity in honeycomb-core panels. All solutions were made for $\lambda = 2$. Results for the case in which the core emissivity is constant but not necessarily equal to the face emissivity (both faces have the same emissivity) are given in table III. Examination of these results shows that the effective conductivity ratio is only weakly influenced by the core emissivity, unless the face emissivity is very low (0.2). Even then, the effect of core emissivity is less than 25 percent.

Some cases were solved in which the face emissivities were different, and the core emissivity was constant and equal to the average value of the face emissivities. The results are summarized in the following table:

Case	ϵ_1	$\epsilon_2 - \epsilon_{11}$	ϵ_{12}	$\frac{k_e A_1}{k \Delta A}$	
				$\overline{T}_1 = 1.6$; $\overline{T}_{12} = 0.8$	$\overline{T}_1 = 2.0$; $\overline{T}_{12} = 1.8$
1	0.8	0.6	0.4	3.364	8.459
2	.4	.6	.8	3.149	8.340
3	.8	.7	.6	3.536	9.375
4	.6	.7	.8	3.437	9.322
5	.6	.6	.6	3.300	8.674

The values of $\frac{k_e A_1}{k \Delta A}$ for case 5 correspond to a constant emissivity equal to the average emissivity of the first two cases. Comparing the constant emissivity value of $\frac{k_e A_1}{k \Delta A}$ for $\overline{T}_1 = 1.6$ and $\overline{T}_{12} = 0.8$ (3.300) with the values for the first two cases gives a difference of less than 5 percent. For $\overline{T}_1 = 2.0$ and $\overline{T}_{12} = 1.8$ the difference is less than 4 percent. Thus, the use of the average face emissivity appears to give satisfactory results.

Some cases were also investigated in which the face emissivities were different and the core emissivity varied linearly through the panel. These results are summarized in the following table:

Case	ϵ_1	ϵ_{12}	$\frac{k_e A_1}{k \Delta A}$	
			$\overline{T}_1 = 1.6$; $\overline{T}_{12} = 0.8$	$\overline{T}_1 = 2.0$; $\overline{T}_{12} = 1.8$
1	0.8	0.4	3.312	8.338
2	.4	.8	3.110	8.237
3	.8	.6	3.525	9.354
4	.6	.8	3.433	9.308

Comparing the first two cases in this table to case 5 in the previous table gives differences of less than 6 percent. Again, using the average face emissivity gives satisfactory results.

Errors Resulting From Uncertainty in Emissivity

In evaluating effective thermal conductivities from the tables or equations presented, the emissivity (assumed to be equal to absorptivity) is likely to be known with least reliability. Suppose that an emissivity ϵ is assumed which may be in error by an amount $\Delta\epsilon$. It is desired to determine the error in the effective conductivity which may result from this uncertainty in the emissivity.

For small values of $\Delta\epsilon$, the following equation is a good approximation:

$$\left(\frac{k_e A_1}{k\,\Delta A} - 1\right)_{\epsilon+\Delta\epsilon} = \left(\frac{k_e A_1}{k\,\Delta A} - 1\right)_{\epsilon} + \frac{\partial}{\partial\epsilon}\left(\frac{k_e A_1}{k\,\Delta A} - 1\right)_{\epsilon} \Delta\epsilon \tag{38}$$

Then, the change in $\frac{k_e A_1}{k\,\Delta A} - 1$ because of the change in ϵ is

$$\Delta\left(\frac{k_e A_1}{k\,\Delta A} - 1\right) = \frac{\partial}{\partial\epsilon}\left(\frac{k_e A_1}{k\,\Delta A} - 1\right)\Delta\epsilon \tag{39}$$

The ratio of the change in $\frac{k_e A_1}{k\,\Delta A} - 1$ to the value of $\frac{k_e A_1}{k\,\Delta A} - 1$ is

$$\frac{\Delta\left(\frac{k_e A_1}{k\,\Delta A} - 1\right)}{\frac{k_e A_1}{k\,\Delta A} - 1} = \frac{\frac{\partial}{\partial\epsilon}\left(\frac{k_e A_1}{k\,\Delta A} - 1\right)\Delta\epsilon}{\frac{k_e A_1}{k\,\Delta A} - 1} \tag{40}$$

Substituting the value of $\frac{k_e A_1}{k\,\Delta A} - 1$ from equation (C4) for honeycomb-core panels yields the following equation:

$$\frac{\Delta\left(\frac{k_e A_1}{k\,\Delta A} - 1\right)}{\frac{k_e A_1}{k\,\Delta A} - 1} = 1.63(\lambda + 1)^{-0.89}\,\frac{\Delta\epsilon}{\epsilon} \tag{41}$$

The error in $\frac{k_e A_1}{k \Delta A} - 1$ is plotted in figure 8 as a function of $\frac{\Delta \epsilon}{\epsilon}$ for several values of λ.

For deep cells (large values of λ), the effect of an error in emissivity is relatively unimportant. However, when the ratio of core height to cell diameter is about 1, a given percentage error in ϵ will lead to a similar percentage error in $\frac{k_e A_1}{k \Delta A} - 1$.

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Comparison of Calculated Results With Experimental Results

Some experimental results of thermal conductivity tests of an adhesively bonded honeycomb panel are given in reference 3. A comparison of these experimental results with results calculated from equation (C4) is given in figure 9. The cells of the test specimen were squares measuring 0.25 inch on each side. The present cylindrical-cell analysis was adapted to the square-cell data by choosing the diameter of the cylinder so that the perimeters of the two cells were equal. Thus,

$\pi d = 4(0.25)$ inch or, $d = \frac{1}{\pi}$ inch.

The tests were performed in a guarded hot plate conforming closely to standards of the American Society of Testing Materials, reference 5, except that the apparatus was designed to test square panels measuring 6 inches on each side. Since the specimen size was considerably less than the recommended size (panels measuring 12 inches on a side), it is likely that the heat passing through the panel was less than the heat supplied by the central heater as a result of heat losses from the sides of the test specimen. This heat loss would cause the experimental conductivity values to be too high.

The k_e curve shown in figure 9 is the sum of the calculated conductive heat transfer $\frac{(k \Delta A)}{A_1}$ and radiant heat transfer and is found from equation (C4). (An emissivity of 0.8 is assumed.) The k curve is the sum of the k_e (effective conductivity) and k_A (air conductivity) curves and gives the calculated thermal conductivity of the panel.

The only experimental results available were for a temperature range in which radiation is not the dominant mode of heat transfer. Because of this fact and because the assumed emissivity of the panel was high (0.8), the present analysis shows little difference from the analysis of reference 3. However, this result is predicted from figure 7 and it is felt that the similarity strengthens the validity of the present analysis.

CONCLUDING REMAKRS

Numerical solutions for the effective thermal conductivity were obtained for a wide range of parameters for honeycomb-core and corrugated-core panels. Simple approximate equations were found which are sufficiently accurate for most design calculations. Equations for the steady-state transfer of heat were formulated.

Effective thermal conductivities, which were greater by an order of magnitude than conductivities due to conduction only, were found in many cases. The effect of thermal radiation was found to increase approximately as a cubic function of the temperature. For honeycomb-core panels, the largest radiation effect occurred with small values of the ratio of core height to cell diameter and large values of emissivity.

A new procedure has been developed to account fully for reflections of radiant energy. In this procedure, the radiant energy was traced through all reflections which occur. The infinite sum which was obtained was then reduced to a closed form by the use of matrix algebra. The effect of the reflections, as compared with the case in which the absorptivity was unity, was considered in detail for honeycomb panels. It was found that, for values of the ratio of core height to cell diameter greater than 0.73, the no-reflection analysis underestimated the heat transfer through the panel. For values less than 0.73, the no-reflection analysis overestimated the heat transfer.

The effect of variable emissivity on effective thermal conductivity was investigated. It was found that the equation for effective thermal conductivity with constant emissivity gave satisfactory results if an emissivity equal to the average emissivity of the two faces was used.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., December 7, 1960.

APPENDIX A

NET RADIATION FACTORS

A net radiation factor is defined as the fraction of the total energy emitted by one element which is absorbed by another element. Thus, $G_{1,2}$ is the fraction of the total energy emitted by element 1 that is absorbed by element 2 after 0, 1, 2, 3, . . . ∞ reflections. Net radiation factors are a function of configuration factors (defined as the fraction of the total energy emitted by one element which is directly incident on another element) and of the absorptivities of the elements. Configuration factors are discussed in appendix B. It should be noted that when the absorptivities of all elements are equal to 1, no reflections occur and the net radiation factors are identical to the configuration factors. A method is now derived for determining net radiation factors in which the infinite number of reflections is expressed in closed form.

Consider a closed system having zero or positive curvature and divided into J elements. Let each element be isothermal and have an absorptivity which is independent of position on the element. Let A_n be the area of the nth element, α_n be its absorptivity, and $F_{n,m}$ be the fraction of the radiant energy leaving element n which is incident on element m.

Now let element n emit energy at a rate q_n per unit area. The rate at which energy is incident on element m as a result of this source at element n is

$$A_n F_{n,m} Q_n$$

This energy is absorbed at a rate

$$\alpha_m Q_n A_n F_{n,m}$$

and reflected at a rate

$$(1 - \alpha_m) Q_n A_n F_{n,m}$$

The same process occurs at every element m'. The energy emitted by element n, reflected by element m', and incident on element m is

$$\left[(1 - \alpha_{m'}) Q_n A_n F_{n,m'}\right] F_{m',m}$$

The element absorbs this energy at a rate

$$\alpha_m\left[(1 - \alpha_{m'})Q_nA_nF_{n,m'}\right]F_{m',m}$$

and reflects it at a rate

$$(1 - \alpha_m)(1 - \alpha_{m'})Q_nA_nF_{n,m'}F_{m',m}$$

The total energy emitted by element n and absorbed by element m after a single reflection is

$$\alpha_mQ_nA_n\sum_{m'=1}^{J}(1 - \alpha_{m'})F_{n,m'}F_{m',m}$$

By using the same procedure, it is found that the energy emitted by element n, reflected by element m', reflected by element m'', and absorbed by element m is

$$\alpha_m(1 - \alpha_{m'})(1 - \alpha_{m''})Q_nA_nF_{n,m'}F_{m',m''}F_{m'',m}$$

The total rate at which energy is emitted by element n and absorbed by element m after two reflections is

$$\alpha_mQ_nA_n\sum_{m'=1}^{J}\sum_{m''=1}^{J}(1 - \alpha_{m'})(1 - \alpha_{m''})F_{n,m'}F_{m',m''}F_{m'',m}$$

Now let $G_{n,m}$ be the fraction of the energy emitted by element n which is absorbed by element m. Then the total energy emitted by element n and absorbed by element m is $A_nq_nG_{n,m}$. This total energy is equal to the sum of the energies absorbed by element m after each reflection as follows:

$$A_nQ_nG_{n,m} = A_nQ_n\alpha_m\left[F_{n,m} + \sum_{m'=1}^{J}(1 - \alpha_{m'})F_{n,m'}F_{m',m}\right.$$

$$\left. + \sum_{m'=1}^{J}\sum_{m''=1}^{J}(1 - \alpha_{m'})(1 - \alpha_{m''})F_{n,m'}F_{m',m''}F_{m'',m} + \ldots\right] \qquad \text{(A1a)}$$

or

$$G_{n,m} = \alpha_m \left[F_{n,m} + \sum_{m'=1}^{J} (1 - \alpha_{m'}) F_{n,m} F_{m',m} + \sum_{m'=1}^{J} \sum_{m''=1}^{J} (1 - \alpha_{m'})(1 - \alpha_{m''}) F_{n,m'} F_{m',m''} F_{m'',m} + \cdots \right] \tag{A1b}$$

The matrices $[F]$, $[G]$, $[\alpha]$, and $[E]$ are defined as follows:

$$[F] = \begin{bmatrix} F_{1,1} & F_{1,2} & \cdots & F_{1,J} \\ F_{2,1} & \cdots & & \cdots \\ \cdots & & & \\ & & & \\ F_{J,1} & \cdots & & F_{J,J} \end{bmatrix} \tag{A2}$$

$$[G] = \begin{bmatrix} G_{1,1} & G_{1,2} & \cdots & G_{1,J} \\ G_{2,1} & \cdots & & \cdots \\ \cdots & & & \\ & & & \\ G_{J,1} & \cdots & & G_{J,J} \end{bmatrix} \tag{A3}$$

$$[\alpha] = \begin{bmatrix} \alpha_1 & 0 & . & . & . & 0 \\ 0 & \alpha_2 & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ 0 & . & . & . & . & \alpha_J \end{bmatrix} \tag{A4}$$

$$[E] = \begin{bmatrix} 1 - \alpha_1 & 0 & . & . & . & 0 \\ 0 & 1 - \alpha_2 & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ 0 & . & . & . & . & 1 - \alpha_J \end{bmatrix} \tag{A5}$$

It will now be proved that

$$[G] = \sum_{i=0}^{\infty} \Big[[F][E]\Big]^i [F][\alpha] \tag{A6}$$

The series in equation (A6) can be expanded as follows:

$$[G] = [F][\alpha] + [F][E][F][\alpha] + [F][E][F][E][F][\alpha] + \ldots \tag{A7}$$

With the use of matrix multiplication, equation (A7) becomes

$$G_{n,m} = F_{n,m}\alpha_m + \sum_{m'=1}^{J}(1 - \alpha_{m'})F_{n,m'}F_{m',m}\alpha_m$$

$$+ \sum_{m'=1}^{J}\sum_{m''=1}^{J} F_{n,m'}(1 - \alpha_{m'})F_{m',m''}(1 - \alpha_{m''})F_{m'',m}\alpha_m + \cdots \qquad (A8)$$

Therefore, the first three terms of $[G]$ are given correctly by equation (A6). Now assume that equation (A6) is correct for the first j reflections. Then the fraction of the emitted energy which is absorbed after the jth reflection is

$$\left[[F][E]\right]^{j}[F][\alpha]$$

and that which is reflected for the $(j + 1)$th time is

$$\left[[F][E]\right]^{j}[F][E] = \left[[F][E]\right]^{j+1} \qquad (A9)$$

The fraction which is absorbed after the $(j + 1)$th reflection is

$$\left[[F][E]\right]^{j+1}[F][\alpha]$$

But this quantity is the fraction predicted by equation (A6) for the $(j + 1)$th reflection. Since it has been proved that if equation (A6) is correct for any $i = j$ it is also correct for $i = j + 1$ and that the first three terms of equation (A6) are correct, equation (A6) must be correct for all values of i.

For any matrix $[M]$ for which the series $\sum_{i=0}^{\infty}[M]^{i}$ converges, the relation

$$\left[[1] - [M]\right]^{-1} = \sum_{i=0}^{\infty}[M]^{i} \qquad (A10)$$

($[1]$ is the unit diagonal matrix) is valid. That this equation is an identity follows if both sides of the equation are multiplied by

$\left[[1] - [M]\right]$ and the right-hand side is expanded and simplified. By using this identity, equation (A6) becomes

$$[G] = \left[[1] - [F][E]\right]^{-1}[F][\alpha] \tag{A11}$$

Each element n emits an amount of energy

$$\sigma \epsilon_n T_n^4 A_n$$

The energy emitted by element n and absorbed by element m is

$$\sigma \epsilon_n A_n T_n^4 G_{n,m}$$

The energy emitted by all elements and absorbed by element m is

$$\sigma \sum_{n=1}^{J} A_n \epsilon_n T_n^4 G_{n,m}$$

The energy emitted by element m is

$$\sigma \epsilon_m T_m^4 A_m$$

The net radiant heat input to any element n is therefore

$$q_r = \sigma \left(\sum_{n=1}^{J} A_n \epsilon_n G_{n,m} T_n^4 - A_m \epsilon_m T_m^4 \right) \Delta\tau \tag{A12}$$

Substitution of the Kronecker delta,

$$\delta_{n,m} = \begin{cases} 1, & n = m \\ 0, & n \neq m \end{cases} \tag{A13}$$

into equation (A12) yields

$$q_r = \sigma \, \Delta\tau \sum_{n=1}^{J} A_n \epsilon_n \left(G_{n,m} - \delta_{n,m}\right) T_n^4 \tag{A14}$$

Relations similar to those for configuration factors exist between the net radiation factors. For example, all energy emitted by an element m must be absorbed by some element of the system

$$\sum_{n=1}^{J} G_{m,n} = 1 \tag{A15}$$

Furthermore, for thermodynamic equilibrium ($T_m = T_n$ for all values of m and n) there can be no net heat transfer between any two elements. Therefore,

$$A_n \epsilon_n G_{n,m} = A_m \epsilon_m G_{m,n} \tag{A16}$$

APPENDIX B

CONFIGURATION FACTORS

The configuration factor $F_{n,m}$ is defined as the fraction of the radiant energy emitted by element n which is incident on element m. The defining equation for the configuration factor is

$$F_{n,m} = \frac{1}{\pi A_n} \int_{A_n} \int_{A_m} \frac{\cos \psi_1 \cos \psi_2}{S^2} \, dA_m \, dA_n \tag{B1}$$

where

S distance between centers of ΔA_n and ΔA_m

$\cos \psi_1$ angle between normal to ΔA_n and S

$\cos \psi_2$ angle between normal to ΔA_m and S

(For a detailed discussion of configuration factors which includes defining equations and values for particular configurations, see refs. 6 and 7.)

In addition to the defining equation, there exist two other relations which are useful in calculating configuration factors and checking the values obtained. Consider a closed system consisting of J isothermal elements. Then,

$$\sum_{k=1}^{J} F_{i,k} = 1 \tag{B2}$$

for all values of $i \leq J$, since all radiation emitted by the element i must be absorbed by one of the elements of the closed system.

By use of equation (B1) and the well-known reciprocity theorem

$$A_k F_{k,i} = A_i F_{i,k}$$

configuration factors were found for the two panels considered. A summary of the respective analyses and results is given in the next two sections.

Honeycomb-Core Panel

The cell of the honeycomb-core panel was idealized as a circular cross-section since it was felt that this adequately represented the various possible shapes. The cylinder was divided into 10 equal segments as shown in figure 1. The elements corresponding to stations 1 and 12 are the faces of the cylinder. Each element is considered an isothermal surface. By using the reciprocity theorem, the following relations between configuration factors can be shown to be valid:

$$\left.\begin{aligned} F_{1,1} &= F_{12,12} = 0 \\ F_{1,12} &= F_{12,1} \\ F_{1,k} &= F_{12,m} = 0.4\lambda F_{k,1} = 0.4\lambda F_{m,12} \end{aligned}\right\} \tag{B3}$$

for $k = 2$, $m = 11$; $k = 3$, $m = 10$; $k = 4$, $m = 9$; . . . ; $k = 11$, $m = 2$. Also,

$$F_{n,n+m} = F_{n+m,n} = F_{n_1,n_1+m} = F_{n_1+m,n_1} \tag{B4}$$

for $n = 2, 3, 4, \ldots 11$; $n_1 = 2, 3, 4, \ldots 11$; $m = 0, 1, 2, 3, \ldots 9$; $n + m \leqq 11$; and $n_1 + m \leqq 11$. Therefore, all configuration factors can be expressed in terms of $F_{n,1}$, $F_{2,n}$, $F_{2,2}$, and $F_{1,12}$. Integration of equation (B1) for the required configuration factors yields

$$F_{n,1} = \frac{1}{20}\left[(n-1)^2\sqrt{\lambda^2 + \left(\frac{10}{n-1}\right)^2} - (n-2)^2\sqrt{\lambda^2 + \left(\frac{10}{n-2}\right)^2} - (2n-3)\lambda\right]$$

$$(n = 2, 3, 4, \ldots 11) \tag{B5}$$

$$F_{2,n} = \frac{1}{20}\left[2\lambda + 2(n-2)^2\sqrt{\lambda^2 + \left(\frac{10}{n-2}\right)^2} - (n-3)^2\sqrt{\lambda^2 + \left(\frac{10}{n-3}\right)^2} - (n-1)^2\sqrt{\lambda^2 + \left(\frac{10}{n-1}\right)^2}\right] \qquad (n = 3, 4, 5, \ldots 11) \tag{B6}$$

$$F_{n,n} = 1 + \frac{1}{10}\left[\lambda - \sqrt{\lambda^2 + (10)^2}\right] \quad (n = 2, 3, 4, \ldots 11) \tag{B7}$$

$$F_{1,12} = 1 + 2\lambda^2 - 2\lambda\sqrt{\lambda^2 + 1} \tag{B8}$$

Direct substitution of equations (B5) and (B8) (with use of the reciprocity theorem) into equation (B2) demonstrates that equation (B2) is satisfied identically for all elements. For example, at element 1, (which is geometrically identical to element 12), it will be shown that

$$\sum_{n=2}^{11} F_{1,n} + F_{1,12} = 1 \tag{B9}$$

From the reciprocity theorem,

$$F_{1,n} = \frac{A_n}{A_1} F_{n,1} = \frac{4}{10} \lambda F_{n,1} \tag{B10}$$

Therefore,

$$\frac{4}{10} \lambda \sum_{n=2}^{11} F_{n,1} + F_{1,12} = 1 \tag{B11}$$

or, from equations (B5) and (B8),

$$\frac{4}{10} \lambda \sum_{n=2}^{11} \frac{1}{20}\left[(n-1)^2\sqrt{\lambda^2 + \left(\frac{10}{n-1}\right)^2} - (n-2)^2\sqrt{\lambda^2 + \left(\frac{10}{n-2}\right)^2} - (2n-3)\lambda\right]$$

$$+ 1 + 2\lambda^2 - 2\lambda\sqrt{\lambda^2 + 1} = 1 \tag{B12}$$

Note that

$$\frac{4\lambda}{10(20)} \sum_{n=2}^{11} - (2n-3)\lambda = -2\lambda^2 \tag{B13}$$

and

$$\left.\begin{aligned}\frac{4\lambda}{10(20)}\sum_{n=2}^{11}-(n-2)^2\sqrt{\lambda^2+\left(\frac{10}{n-2}\right)^2}&=\frac{4\lambda}{10(20)}\sum_{m+1=2}^{m+1=11}-(m+1-2)^2\sqrt{\lambda^2+\left(\frac{10}{m+1-2}\right)^2}\\&=\frac{4\lambda}{10(20)}\sum_{m=1}^{10}-(m-1)^2\sqrt{\lambda^2+\left(\frac{10}{m-1}\right)^2}\\&=\frac{4\lambda}{10(20)}\sum_{n=2}^{11}-(n-1)^2\sqrt{\lambda^2+\left(\frac{10}{n-1}\right)^2}+\frac{4\lambda}{10(20)}(10)^2\sqrt{\lambda^2+1}\end{aligned}\right\}\quad(B14)$$

Substituting these results into equation (B12) yields

$$\frac{4\lambda}{10(20)}\left[\sum_{n=2}^{11}(n-1)^2\sqrt{\lambda^2+\left(\frac{10}{n-1}\right)^2}-\sum_{n=2}^{11}(n-1)^2\sqrt{\lambda^2+\left(\frac{10}{n-1}\right)^2}\right]$$

$$+2\lambda\sqrt{\lambda^2+1}-2\lambda^2+1+2\lambda^2-2\lambda\sqrt{\lambda^2+1}\equiv 1\qquad(B15)$$

Corrugated-Core Panel

The corrugated-core panel considered is shown in figure 2. In this report the angle ϕ was 45° and the width was considered to be infinite. Integration of equation (B1) yields

$$F_{n,m}=\frac{1}{2}\left[\frac{b}{a}+1-\sqrt{\left(\frac{b}{a}\right)^2-\sqrt{2}\,\frac{b}{a}+1}\right]\qquad(B16)$$

where a is one side of element n and b is one side of element m.

By using the reciprocity theorem and equation (B16) the following relations between configuration factors were found:

$$\left.\begin{aligned}F_{m,n}&=\frac{5}{4}\sqrt{2}F_{n,m}\qquad(m=1,\ 12;\ n=5,\ 6,\ 7,\ 8)\\F_{i,n}&=\frac{5}{8}\sqrt{2}F_{n,i}\qquad(i=2,\ 3,\ 10,\ 11;\ n=5,\ 6,\ 7,\ 8)\end{aligned}\right\}\qquad(B17)$$

All the remaining configuration factors are zero.

APPENDIX C

Approximate Equations

Because of the complexity of the method required to obtain effective thermal conductivity ratios, it seemed desirable to find a simple equation for each panel which would yield approximate values suitable for most design work.

Equation for Honeycomb-Core Panel

The equation for the honeycomb-core panel was found as follows. The expression for the overall heat transfer through the panel in dimensionless form is given by the left side of equation (14) which is

$$\frac{k_e A_1}{k\ \Delta A}\left(\bar{T}_1 - \bar{T}_{12}\right)$$

For conduction only, the conductivity ratio must be equal to 1 or

$$\frac{k_e A_1}{k\ \Delta A}\left(\bar{T}_1 - \bar{T}_{12}\right) = \left(\bar{T}_1 - \bar{T}_{12}\right) \qquad (C1)$$

The effect of radiation must also be considered. Radiation is a function of geometry λ, emissivity ϵ, and the fourth power of the temperatures. Therefore, an equation of the following form was assumed for k_e:

$$\frac{k_e A_1}{k\ \Delta A}\left(\bar{T}_1 - \bar{T}_{12}\right) = \left(\bar{T}_1 - \bar{T}_{12}\right) + f(\lambda, \epsilon)\left(\bar{T}_1^{\,4} - \bar{T}_{12}^{\,4}\right) \qquad (C2)$$

It was found that for each combination of λ and ϵ the data points in the form $\frac{k_e A_1}{k\ \Delta A} - 1$ could be approximated by a linear function of $\left(\bar{T}_1^{\,2} + \bar{T}_{12}^{\,2}\right)\left(\bar{T}_1 + \bar{T}_{12}\right)$, or

$$\frac{\frac{k_e A_1}{k\ \Delta A} - 1}{\left(\bar{T}_1^{\,2} + \bar{T}_{12}^{\,2}\right)\left(\bar{T}_1 + \bar{T}_{12}\right)} = \text{Constant (for each combination of } \lambda \text{ and } \epsilon) = f(\lambda, \epsilon) \qquad (C3)$$

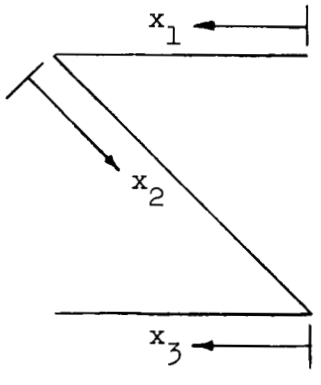
In order to find a general equation for the effective conductivity ratio, it was then necessary to find an analytic expression for the variation of this function in terms of λ and ϵ. Such an expression was found by a process of trial and error. The resulting equation for the effective conductivity ratio is

$$\frac{k_e A_1}{k\,\Delta A} = 1 + 0.664(\lambda + 0.3)^{-0.69}\epsilon^{1.63(\lambda+1)^{-0.89}}\left(\overline{T}_1^{\,2} + \overline{T}_{12}^{\,2}\right)\left(\overline{T}_1 + \overline{T}_{12}\right) \quad (C4)$$

Equation (C4) is based upon 1,200 calculated values of effective thermal conductivity ratio with a maximum deviation of 6.5 percent.

Equation for Corrugated-Core Panel

The same general procedure was used to determine the equation for the corrugated-core panel as was used for the honeycomb-core panel. The major difference in the procedure was that the conduction-only term was found by solution of appropriate differential equations for conduction through the corrugated-core panel. With reference to the following sketch and by denoting the upper face as 1, the corrugation as 2, and the lower face as 3, the equations are as follows:



$$\left.\begin{aligned} k_1 t_1 \frac{d^2 T_1}{dx_1^{\,2}} &= -Q \\ \frac{d^2 T_2}{dx_2^{\,2}} &= 0 \\ k_3 t_3 \frac{d^2 T_3}{dx_3^{\,2}} &= h\left(T_3 - T_a\right) \end{aligned}\right\} \quad (C5)$$

Boundary conditions are

$$\left.\begin{aligned} x_1 = 0;\ \frac{dT_1}{dx_1} &= 0 \\ x_1 = l,\ x_2 = 0;\ T_1 = T_2,\ \frac{dT_1}{dx_1} &= \frac{k_2 t_2}{k_1 t_1}\frac{dT_2}{dx_2} \end{aligned}\right\} \quad (C6)$$

(Equations continued on next page)

$$\left.\begin{aligned} &x_2 = \sqrt{2}l, \quad x_3 = 0; \; T_2 = T_3, \quad \frac{dT_2}{dx_2} = \frac{k_3 t_3}{k_2 t_2}\frac{dT_3}{dx_3} \\ &x_3 = l; \; \frac{dT_3}{dx_3} = 0 \end{aligned}\right\} \tag{C6}$$

Equations (C5) with boundary conditions given by equations (C6) were solved, and the expressions of equations (20) were introduced. The resulting expressions were substituted in equation (27) and gave the effective conductivity ratio (for conduction only) as

$$\frac{k_{e,c}}{k_w \bar{X}} = \frac{1}{\bar{Y}\left\{\left(1 - \frac{\bar{X}}{\sqrt{2}}\right)^2\left(\frac{1}{3} + \frac{\sqrt{2}}{\bar{Y}}\right) + \frac{\left(1 + \frac{\bar{X}}{\sqrt{2}}\right)\coth\left[\sqrt{\bar{h}}\left(1 + \frac{\bar{X}}{\sqrt{2}}\right)\right]}{\sqrt{\bar{h}}} - \frac{1}{\bar{h}}\right\}} \tag{C7}$$

By the same reasoning used to find the equation for the honeycomb-core panel an equation of the following form was assumed for the effective conductivity ratio of the corrugated-core panel:

$$\frac{k_e}{k_w \bar{X}} - \frac{k_{e,c}}{k_w \bar{X}} = f(\bar{Y}, \bar{X}, \epsilon)\left(\bar{T}_{H,av}^2 + \bar{T}_{C,av}^2\right)\left(\bar{T}_{H,av} + \bar{T}_{C,av}\right) \tag{C8}$$

The final equation with $f(\bar{Y}, \bar{X}, \epsilon)$ evaluated is

$$\frac{k_e}{k_w \bar{X}} = \frac{k_{e,c}}{k_w \bar{X}} + 0.298\,\frac{(\bar{X})^{-0.045}}{\bar{Y}}(\epsilon + 0.21)^{1.8}\left(\bar{T}_{H,av}^2 + \bar{T}_{C,av}^2\right)\left(\bar{T}_{H,av} + \bar{T}_{C,av}\right) \tag{C9}$$

Equation (C9) gives a maximum deviation of 11 percent compared with the calculated data. The deviation is larger for the corrugated-core panel than for the honeycomb-core panel because the dependence on the temperature parameter $\left(\bar{T}_{H,av}^2 + \bar{T}_{C,av}^2\right)\left(\bar{T}_{H,av} + \bar{T}_{C,av}\right)$ is not so well approximated by the first power. If the effective conductivity ratio is multiplied by a correction factor

$$1.136\left[\left(\bar{T}_{H,av}^{\,2} + \bar{T}_{C,av}^{\,2}\right)\left(\bar{T}_{H,av} + \bar{T}_{C,av}\right)\right]^{-0.0425}$$

the deviation is reduced to less than 6 percent.

L
1
2
3
5

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TABLE I.- CALCULATED EFFECTIVE THERMAL CONDUCTIVITY

RATIOS FOR HONEYCOMB-CORE PANELS

(a) $\lambda = 1$

$\bar{T}_1$	$\bar{T}_{12}$	$\frac{k_e A_1}{k \Delta A}$ for -				
		$\epsilon = 1.0$	$\epsilon = 0.8$	$\epsilon = 0.6$	$\epsilon = 0.4$	$\epsilon = 0.2$
0.3	0.10	1.023	1.019	1.015	1.011	1.006
	.15	1.029	1.024	1.019	1.014	1.007
	.20	1.037	1.031	1.025	1.018	1.010
	.25	1.048	1.041	1.032	1.023	1.013
0.4	0.20	1.069	1.057	1.046	1.033	1.018
	.25	1.083	1.070	1.055	1.040	1.022
	.30	1.101	1.084	1.067	1.048	1.026
	.35	1.122	1.102	1.081	1.058	1.032
0.5	0.30	1.156	1.131	1.104	1.074	1.040
	.35	1.182	1.153	1.121	1.087	1.047
	.40	1.212	1.178	1.142	1.101	1.055
	.45	1.247	1.207	1.165	1.118	1.064
0.6	0.40	1.298	1.250	1.199	1.142	1.077
	.45	1.339	1.284	1.226	1.162	1.088
	.50	1.385	1.323	1.257	1.184	1.100
	.55	1.437	1.367	1.292	1.209	1.114
0.7	0.50	1.509	1.427	1.339	1.243	1.132
	.55	1.568	1.476	1.378	1.271	1.148
	.60	1.633	1.531	1.422	1.302	1.165
	.65	1.705	1.591	1.470	1.337	1.184
0.8	0.40	1.548	1.459	1.364	1.260	1.142
	.50	1.662	1.554	1.440	1.315	1.172
	.60	1.801	1.671	1.533	1.382	1.208
	.70	1.968	1.811	1.645	1.462	1.252
0.9	0.50	1.848	1.709	1.563	1.403	1.219
	.60	2.002	1.839	1.666	1.477	1.260
	.70	2.186	1.993	1.789	1.565	1.309
	.80	2.403	2.175	1.933	1.669	1.366
1.0	0.60	2.241	2.038	1.824	1.589	1.321
	.70	2.442	2.207	1.958	1.686	1.375
	.80	2.678	2.403	2.115	1.799	1.437
	.90	2.950	2.631	2.295	1.928	1.508
1.2	0.80	3.356	2.968	2.561	2.117	1.611
	.90	3.669	3.229	2.768	2.266	1.694
	1.00	4.025	3.524	3.001	2.434	1.787
	1.10	4.425	3.856	3.264	2.622	1.891
1.4	0.60	3.633	3.196	2.738	2.240	1.676
	.80	4.229	3.693	3.133	2.525	1.835
	1.00	4.987	4.322	3.630	2.883	2.034
	1.20	5.934	5.104	4.246	3.324	2.280
1.6	0.80	5.321	4.597	3.845	3.032	2.113
	1.00	6.176	5.304	4.402	3.433	2.337
	1.20	7.226	6.169	5.082	3.920	2.609
	1.40	8.496	7.213	5.898	4.501	2.934
2.0	1.20	10.604	8.943	7.247	5.455	3.459
	1.40	12.118	10.180	8.208	6.136	3.839
	1.60	13.893	11.626	9.327	6.926	4.279
	1.80	15.953	13.301	10.621	7.835	4.781

TABLE I.- CALCULATED EFFECTIVE THERMAL CONDUCTIVITY

RATIOS FOR HONEYCOMB-CORE PANELS - Continued

(b) $\lambda = 2$

$\bar{T}_1$	$\bar{T}_{12}$	$\frac{k_e A_1}{k \Delta A}$ for -				
		$\epsilon = 1.0$	$\epsilon = 0.8$	$\epsilon = 0.6$	$\epsilon = 0.4$	$\epsilon = 0.2$
0.3	0.10	1.016	1.014	1.012	1.010	1.006
	.15	1.020	1.018	1.016	1.013	1.008
	.20	1.026	1.023	1.020	1.016	1.011
	.25	1.034	1.030	1.026	1.021	1.014
0.4	0.20	1.048	1.043	1.037	1.030	1.019
	.25	1.058	1.052	1.045	1.036	1.023
	.30	1.070	1.063	1.055	1.044	1.028
	.35	1.085	1.077	1.067	1.054	1.034
0.5	0.30	1.108	1.098	1.085	1.068	1.044
	.35	1.126	1.114	1.099	1.080	1.051
	.40	1.147	1.133	1.116	1.093	1.060
	.45	1.172	1.155	1.135	1.109	1.070
0.6	0.40	1.207	1.187	1.163	1.131	1.084
	.45	1.235	1.213	1.185	1.149	1.096
	.50	1.267	1.241	1.210	1.169	1.109
	.55	1.303	1.274	1.239	1.192	1.123
0.7	0.50	1.353	1.319	1.277	1.223	1.143
	.55	1.394	1.356	1.309	1.249	1.160
	.60	1.439	1.396	1.345	1.278	1.178
	.65	1.489	1.441	1.384	1.309	1.198
0.8	0.40	1.380	1.343	1.297	1.239	1.153
	.50	1.459	1.414	1.360	1.289	1.185
	.60	1.555	1.501	1.436	1.350	1.225
	.70	1.671	1.605	1.526	1.423	1.272
0.9	0.50	1.588	1.529	1.460	1.369	1.236
	.60	1.695	1.626	1.544	1.437	1.280
	.70	1.822	1.741	1.644	1.517	1.332
	.80	1.972	1.875	1.760	1.611	1.393
1.0	0.60	1.860	1.774	1.672	1.539	1.346
	.70	2.000	1.900	1.781	1.627	1.403
	.80	2.163	2.046	1.907	1.729	1.469
	.90	2.351	2.214	2.052	1.845	1.544
1.2	0.80	2.633	2.465	2.267	2.016	1.653
	.90	2.849	2.658	2.434	2.149	1.740
	1.00	3.095	2.876	2.621	2.299	1.837
	1.10	3.370	3.121	2.830	2.465	1.944
1.4	0.60	2.826	2.636	2.411	2.126	1.719
	.80	3.238	3.003	2.728	2.381	1.886
	1.00	3.762	3.468	3.126	2.698	2.093
	1.20	4.415	4.044	3.617	3.087	2.345
1.6	0.80	3.996	3.675	3.300	2.832	2.174
	1.00	4.586	4.196	3.745	3.185	2.405
	1.20	5.310	4.833	4.285	3.612	2.681
	1.40	6.187	5.601	4.932	4.118	3.006
2.0	1.20	7.655	6.888	6.012	4.955	3.532
	1.40	8.700	7.797	6.772	5.543	3.907
	1.60	9.925	8.860	7.656	6.223	4.336
	1.80	11.347	10.090	8.674	7.001	4.821

TABLE I.- CALCULATED EFFECTIVE THERMAL CONDUCTIVITY

RATIOS FOR HONEYCOMB-CORE PANELS - Continued

(c) $\lambda = 3$

$\bar{T}_1$	$\bar{T}_{12}$	$\frac{k_e A_1}{k \Delta A}$ for -				
		$\epsilon = 1.0$	$\epsilon = 0.8$	$\epsilon = 0.6$	$\epsilon = 0.4$	$\epsilon = 0.2$
0.3	0.10	1.012	1.011	1.010	1.009	1.006
	.15	1.015	1.014	1.013	1.011	1.008
	.20	1.020	1.019	1.017	1.014	1.010
	.25	1.025	1.024	1.022	1.018	1.013
0.4	0.20	1.037	1.034	1.031	1.026	1.019
	.25	1.044	1.041	1.037	1.032	1.023
	.30	1.053	1.050	1.045	1.039	1.028
	.35	1.064	1.060	1.054	1.046	1.033
0.5	0.30	1.083	1.077	1.070	1.060	1.043
	.35	1.097	1.090	1.082	1.070	1.050
	.40	1.112	1.105	1.095	1.081	1.058
	.45	1.129	1.120	1.109	1.093	1.065
0.6	0.40	1.159	1.148	1.134	1.115	1.082
	.45	1.180	1.168	1.152	1.130	1.093
	.50	1.203	1.189	1.172	1.147	1.104
	.55	1.226	1.210	1.190	1.162	1.114
0.7	0.50	1.270	1.252	1.228	1.195	1.139
	.55	1.300	1.280	1.254	1.217	1.154
	.60	1.332	1.309	1.280	1.239	1.170
	.65	1.362	1.336	1.303	1.258	1.180
0.8	0.40	1.292	1.272	1.246	1.210	1.150
	.50	1.352	1.328	1.297	1.254	1.181
	.60	1.425	1.395	1.358	1.306	1.218
	.70	1.507	1.471	1.426	1.363	1.257
0.9	0.50	1.452	1.420	1.380	1.324	1.231
	.60	1.533	1.495	1.449	1.383	1.273
	.70	1.628	1.583	1.528	1.451	1.321
	.80	1.732	1.678	1.612	1.521	1.368
1.0	0.60	1.661	1.614	1.555	1.473	1.337
	.70	1.766	1.711	1.643	1.549	1.391
	.80	1.887	1.822	1.742	1.633	1.449
	.90	2.013	1.937	1.844	1.716	1.504
1.2	0.80	2.253	2.160	2.045	1.889	1.632
	.90	2.415	2.309	2.178	2.001	1.711
	1.00	2,593	2,471	2,321	2.120	1.793
	1.10	2.766	2.626	2.455	2.226	1.857
1.4	0.60	2.406	2.300	2.168	1.990	1.700
	.80	2.722	2.590	2.428	2.210	1.859
	1.00	3.118	2.952	2.750	2.480	2.050
	1.20	3.590	3.379	3.124	2.787	2.257
1.6	0.80	3.308	3.126	2.903	2.606	2.136
	1.00	3.758	3.536	3.266	2.909	2.351
	1.20	4.303	4.028	3.699	3.266	2.598
	1.40	4.922	4.583	4.177	3.650	2.848
2.0	1.20	6.127	5.679	5.142	4.449	3.414
	1.40	6.918	6.387	5.754	4.944	3.750
	1.60	7.824	7.193	6.444	5.493	4.110
	1.80	8.775	8.026	7.139	6.021	4.417

TABLE I.- CALCULATED EFFECTIVE THERMAL CONDUCTIVITY

RATIOS FOR HONEYCOMB-CORE PANELS - Continued

(d) $\lambda = 5$

$\bar{T}_1$	$\bar{T}_{12}$	$\frac{k_e A_1}{k \Delta A}$ for -				
		$\epsilon = 1.0$	$\epsilon = 0.8$	$\epsilon = 0.6$	$\epsilon = 0.4$	$\epsilon = 0.2$
0.3	0.10	1.009	1.008	1.008	1.007	1.006
	.15	1.011	1.010	1.010	1.009	1.007
	.20	1.014	1.013	1.013	1.012	1.009
	.25	1.018	1.017	1.016	1.015	1.012
0.4	0.20	1.026	1.025	1.023	1.021	1.017
	.25	1.031	1.030	1.028	1.026	1.021
	.30	1.038	1.036	1.034	1.031	1.025
	.35	1.046	1.044	1.041	1.038	1.030
0.5	0.30	1.059	1.056	1.053	1.048	1.039
	.35	1.068	1.066	1.062	1.056	1.046
	.40	1.080	1.076	1.072	1.066	1.053
	.45	1.092	1.088	1.083	1.076	1.061
0.6	0.40	1.112	1.108	1.102	1.092	1.075
	.45	1.128	1.122	1.115	1.105	1.085
	.50	1.144	1.138	1.130	1.119	1.096
	.55	1.162	1.155	1.146	1.133	1.107
0.7	0.50	1.192	1.184	1.173	1.158	1.128
	.55	1.214	1.204	1.193	1.175	1.142
	.60	1.237	1.227	1.214	1.195	1.157
	.65	1.261	1.249	1.235	1.213	1.172
0.8	0.40	1.207	1.198	1.186	1.169	1.136
	.50	1.250	1.239	1.225	1.204	1.165
	.60	1.302	1.288	1.272	1.247	1.200
	.70	1.362	1.346	1.326	1.296	1.239
0.9	0.50	1.320	1.306	1.287	1.261	1.210
	.60	1.378	1.361	1.340	1.309	1.249
	.70	1.447	1.427	1.402	1.365	1.294
	.80	1.524	1.500	1.470	1.426	1.343
1.0	0.60	1.469	1.447	1.420	1.381	1.307
	.70	1.544	1.520	1.488	1.443	1.357
	.80	1.632	1.603	1.566	1.513	1.413
	.90	1.728	1.693	1.650	1.588	1.473
1.2	0.80	1.891	1.848	1.795	1.718	1.577
	.90	2.008	1.960	1.898	1.811	1.651
	1.00	2.139	2.083	2.012	1.913	1.732
	1.10	2.275	2.210	2.129	2.015	1.810
1.4	0.60	1.997	1.948	1.886	1.797	1.636
	.80	2.224	2.163	2.086	1.977	1.782
	1.00	2.510	2.433	2.336	2.200	1.959
	1.10	2.857	2.758	2.635	2.464	2.165
1.6	0.80	2.641	2.556	2.449	2.298	2.032
	1.00	2.966	2.861	2.730	2.548	2.230
	1.20	3.360	3.230	3.068	2.845	2.462
	1.40	3.822	3.659	3.458	3.183	2.719
2.0	1.20	4.662	4.446	4.175	3.806	3.195
	1.40	5.234	4.975	4.653	4.218	3.507
	1.60	5.897	5.586	5.201	4.685	3.855
	1.80	6.626	6.253	5.793	5.179	4.206

TABLE I.- CALCULATED EFFECTIVE THERMAL CONDUCTIVITY

RATIOS FOR HONEYCOMB-CORE PANELS - Concluded

(e) $\lambda = 10$

$\bar{T}_1$	$\bar{T}_{12}$	$\frac{k_e A_1}{k \Delta A}$ for -				
		$\epsilon = 1.0$	$\epsilon = 0.8$	$\epsilon = 0.6$	$\epsilon = 0.4$	$\epsilon = 0.2$
0.3	0.10	1.006	1.005	1.005	1.005	1.004
	.15	1.007	1.007	1.007	1.006	1.006
	.20	1.009	1.009	1.009	1.008	1.007
	.25	1.012	1.011	1.011	1.011	1.010
0.4	0.20	1.017	1.016	1.016	1.015	1.014
	.25	1.020	1.020	1.019	1.018	1.016
	.30	1.025	1.024	1.023	1.022	1.020
	.35	1.029	1.029	1.028	1.027	1.024
0.5	0.30	1.038	1.037	1.036	1.034	1.031
	.35	1.044	1.043	1.042	1.040	1.036
	.40	1.052	1.050	1.049	1.047	1.042
	.45	1.059	1.058	1.056	1.053	1.048
0.6	0.40	1.073	1.071	1.069	1.066	1.059
	.45	1.083	1.081	1.078	1.075	1.067
	.50	1.094	1.091	1.088	1.084	1.076
	.55	1.104	1.101	1.098	1.093	1.084
0.7	0.50	1.125	1.122	1.118	1.112	1.101
	.55	1.139	1.135	1.131	1.125	1.112
	.60	1.153	1.150	1.145	1.138	1.124
	.65	1.167	1.162	1.157	1.149	1.134
0.8	0.40	1.135	1.131	1.127	1.120	1.108
	.50	1.162	1.158	1.153	1.146	1.131
	.60	1.196	1.191	1.185	1.176	1.158
	.70	1.234	1.228	1.221	1.210	1.188
0.9	0.50	1.208	1.203	1.196	1.186	1.167
	.60	1.246	1.240	1.232	1.220	1.197
	.70	1.290	1.283	1.274	1.260	1.233
	.80	1.338	1.329	1.318	1.302	1.270
1.0	0.60	1.305	1.297	1.287	1.272	1.243
	.70	1.354	1.345	1.333	1.317	1.283
	.80	1.410	1.400	1.386	1.366	1.327
	.90	1.469	1.456	1.440	1.417	1.371
1.2	0.80	1.581	1.565	1.544	1.515	1.459
	.90	1.657	1.638	1.615	1.582	1.518
	1.00	1.740	1.719	1.692	1.654	1.580
	1.10	1.821	1.796	1.765	1.721	1.637
1.4	0.60	1.650	1.631	1.606	1.572	1.506
	.80	1.799	1.775	1.746	1.703	1.623
	1.00	1.986	1.956	1.918	1.865	1.765
	1.20	2.207	2.168	2.120	2.052	1.927
1.6	0.80	2.072	2.039	1.996	1.936	1.824
	1.00	2.285	2.244	2.192	2.119	1.984
	1.20	2.542	2.491	2.426	2.335	2.171
	1.40	2.834	2.769	2.687	2.574	2.372
2.0	1.20	3.402	3.314	3.201	3.043	2.768
	1.40	3.776	3.669	3.534	3.346	3.022
	1.60	4.205	4.075	3.911	3.685	3.301
	1.80	4.655	4.498	4.298	4.025	3.567

TABLE II.- NET RADIATION FACTORS FOR HONEYCOMB-CORE PANELS

(a) $\lambda = 1$

n	$G_{n,m}$ at -											
	m = 1	m = 2	m = 3	m = 4	m = 5	m = 6	m = 7	m = 8	m = 9	m = 10	m = 11	m = 12
						$\alpha = 1.0$						
1	0	1810×10^{-4}	1470×10^{-4}	1185×10^{-4}	9520×10^{-5}	7640×10^{-5}	6140×10^{-5}	4950×10^{-5}	4010×10^{-5}	3260×10^{-5}	2680×10^{-5}	1716×10^{-4}
2	4525×10^{-4}	9500×10^{-5}	8520×10^{-5}	7110×10^{-5}	5820	4700	3750	2970	2350	1860	1470	6690×10^{-5}
3	3673	8520	9500	8520	7110	5820	4700	3750	2970	2350	1860	8160
4	2962	7110	8520	9500	8520	7110	5820	4700	3750	2970	2350	1002×10^{-4}
5	2380	5820	7110	8520	9500	8520	7110	5820	4700	3750	2970	1237
6	1910	4700	5820	7110	8520	9500	8520	7110	5820	4700	3750	1535
7	1535	3750	4700	5820	7110	8520	9500	8520	7110	5820	4700	1910
8	1237	2970	3750	4700	5820	7110	8520	9500	8520	7110	5820	2380
9	1002	2350	2970	3750	4700	5820	7110	8520	9500	8520	7110	2962
10	8160×10^{-5}	1860	2350	2970	3750	4700	5820	7110	8520	9500	8520	3673
11	6690	1470	1860	2350	2970	3750	4700	5820	7110	8520	9500	4525
12	1716×10^{-4}	2680	3260	4010	4950	6140	7640	9520	1185×10^{-4}	1470×10^{-4}	1810×10^{-4}	0
						$\alpha = 0.8$						
1	4806×10^{-5}	1571×10^{-4}	1308×10^{-4}	1083×10^{-4}	8957×10^{-5}	7424×10^{-5}	6185×10^{-5}	5193×10^{-5}	4408×10^{-5}	3790×10^{-5}	3324×10^{-5}	1631×10^{-4}
2	3928×10^{-4}	9708×10^{-5}	8734×10^{-5}	7421×10^{-5}	6215	5159	4257	3509	2910	2435	2061	8301×10^{-5}
3	3267	8733	9389	8473	7212	6052	5036	4169	3453	2883	2435	9481
4	2706	7421	8473	9178	8307	7087	5962	4979	4141	3453	2910	1102×10^{-4}
5	2239	6215	7213	8307	9051	8216	7028	5934	4979	4169	3509	1298
6	1856	5159	6052	7087	8216	8992	8187	7028	5962	5037	4257	1546
7	1546	4257	5037	5962	7028	8187	8992	8216	7087	6052	5159	1856
8	1298	3509	4169	4979	5934	7028	8216	9051	8307	7213	6215	2239
9	1102	2910	3453	4141	4979	5962	7087	8307	9178	8473	7421	2706
10	9481×10^{-5}	2435	2883	3453	4169	5036	6052	7212	8473	9389	8733	3267
11	8301	2061	2435	2910	3509	4257	5159	6215	7421	8734	9708	3928
12	1631×10^{-4}	3324	3790	4408	5193	6185	7424	8957	1083×10^{-4}	1308×10^{-4}	1571×10^{-4}	4806×10^{-5}
						$\alpha = 0.6$						
1	8827×10^{-5}	1344×10^{-4}	1151×10^{-4}	9833×10^{-5}	8412×10^{-5}	7228×10^{-5}	6256×10^{-5}	5469×10^{-5}	4845×10^{-5}	4357×10^{-5}	3997×10^{-5}	1583×10^{-4}
2	3361×10^{-4}	9566×10^{-5}	8693×10^{-5}	7563	6516	5590	4790	4122	3582	3154	2821	9986×10^{-5}
3	2877	8692	9085	8292	7237	6257	5392	4648	4031	3538	3154	1090×10^{-4}
4	2458	7562	8292	8756	8030	7035	6112	5298	4602	4031	3582	1211
5	2103	6516	7237	8030	8553	7882	6940	6065	5298	4648	4122	1367
6	1807	5590	6258	7036	7882	8457	7835	6940	6112	5393	4790	1564
7	1564	4790	5393	6112	6940	7835	8457	7882	7036	6258	5590	1807
8	1367	4122	4648	5298	6065	6940	7882	8553	8030	7237	6516	2103
9	1211	3582	4031	4602	5298	6112	7035	8030	8756	8292	7562	2458
10	1090	3154	3538	4031	4648	5392	6257	7237	8292	9085	8692	2877
11	9986×10^{-5}	2821	3154	3582	4122	4790	5590	6516	7563	8693	9566	3361
12	1583×10^{-4}	3997	4357	4845	5469	6256	7228	8412	9833	1151×10^{-4}	1344×10^{-4}	8827×10^{-5}
						$\alpha = 0.4$						
1	1213×10^{-4}	1123×10^{-4}	9960×10^{-5}	8836×10^{-5}	7866×10^{-5}	7042×10^{-5}	6355×10^{-5}	5793×10^{-5}	5345×10^{-5}	4995×10^{-5}	4742×10^{-5}	1571×10^{-4}
2	2807	9054×10^{-5}	8373	7514	6709	5989	5360	4829	4397	4054	3790	1185
3	2489	8372	8564	7957	7170	6433	5775	5204	4729	4348	4054	1249
4	2209	7514	7957	8218	7677	6953	6274	5671	5154	4728	4397	1336
5	1966	6710	7171	7677	7998	7516	6847	6222	5671	5204	4829	1448
6	1760	5989	6434	6953	7516	7893	7464	6847	6274	5775	5361	1589
7	1589	5361	5775	6274	6847	7464	7893	7516	6953	6434	5989	1760
8	1448	4829	5204	5671	6222	6847	7516	7998	7677	7171	6710	1966
9	1336	4397	4728	5154	5671	6274	6953	7677	8218	7957	7514	2209
10	1249	4054	4348	4729	5204	5775	6433	7170	7957	8564	8372	2489
11	1185	3790	4054	4397	4829	5360	5989	6709	7514	8373	9054	2807
12	1571	4742	4995	5345	5793	6355	7042	7866	8836	9960	1123×10^{-4}	1213
						$\alpha = 0.2$						
1	1475×10^{-4}	8998×10^{-5}	8368×10^{-5}	7798×10^{-5}	7294×10^{-5}	6859×10^{-5}	6489×10^{-5}	6183×10^{-5}	5937×10^{-5}	5745×10^{-5}	5608×10^{-5}	1597×10^{-4}
2	2249	8119	7725	7237	6773	6351	5979	5661	5401	5193	5036	1402
3	2091	7724	7782	7434	6992	6573	6194	5863	5586	5363	5194	1436
4	1949	7236	7434	7536	7232	6832	6455	6117	5825	5586	5401	1484
5	1823	6773	6992	7232	7375	7113	6754	6415	6117	5863	5661	1545
6	1714	6352	6573	6833	7113	7297	7074	6754	6455	6195	5980	1622
7	1622	5980	6195	6455	6754	7074	7297	7113	6833	6573	6352	1714
8	1545	5661	5863	6117	6415	6754	7113	7375	7232	6992	6773	1823
9	1484	5401	5586	5825	6117	6455	6832	7232	7536	7434	7236	1949
10	1436	5194	5363	5586	5863	6194	6573	6992	7434	7782	7724	2091
11	1402	5036	5193	5401	5661	5979	6351	6773	7237	7725	8119	2249
12	1597	5608	5745	5937	6183	6489	6859	7294	7798	8368	8998	1475

TABLE II.- NET RADIATION FACTORS FOR HONEYCOMB-CORE PANELS - Continued

(b) $\lambda = 2$

n	$G_{n,m}$ at -											
	m = 1	m = 2	m = 3	m = 4	m = 5	m = 6	m = 7	m = 8	m = 9	m = 10	m = 11	m = 12
						$\alpha = 1.0$						
1	0	3280×10^{-4}	2137×10^{-4}	1378×10^{-4}	8960×10^{-5}	5940×10^{-5}	4050×10^{-5}	2840×10^{-5}	2040×10^{-5}	1510×10^{-5}	1140×10^{-5}	5570×10^{-5}
2	4099×10^{-4}	1802	1427	9490×10^{-5}	6030	3770	2370	1510	9900×10^{-6}	6700×10^{-6}	4600×10^{-6}	1430
3	2671	1427	1802	1427×10^{-4}	9490	6030	3770	2370	1510×10^{-5}	9900	6700	1890
4	1722	9490×10^{-5}	1427	1802	1427×10^{-4}	9490	6030	3770	2370	1510×10^{-5}	9900	2560
5	1120	6030	9490×10^{-5}	1427	1802	1427×10^{-4}	9490	6030	3770	2370	1510×10^{-5}	3550
6	7430×10^{-5}	3770	6030	9490×10^{-5}	1427	1802	1427×10^{-4}	9490	6030	3770	2370	5060
7	5060	2370	3770	6030	9490×10^{-5}	1427	1802	1427×10^{-4}	9490	6030	3770	7430
8	3550	1510	2370	3770	6030	9490×10^{-5}	1427	1802	1427×10^{-4}	9490	6030	1120×10^{-4}
9	2560	9900×10^{-6}	1510	2370	3770	6030	9490×10^{-5}	1427	1802	1427×10^{-4}	9490	1722
10	1890	6700	9900×10^{-6}	1510	2370	3770	6030	9490×10^{-5}	1427	1802	1427×10^{-4}	2671
11	1430	4600	6700	9900×10^{-6}	1510	2370	3770	6030	9490×10^{-5}	1427	1802	4099
12	5570	1140×10^{-5}	1510×10^{-5}	2040×10^{-5}	2840	4050	5940	8960	1378×10^{-4}	2137	3280	0
						$\alpha = 0.8$						
1	4287×10^{-5}	2857×10^{-4}	1950×10^{-4}	1321×10^{-4}	9028×10^{-5}	6273×10^{-5}	4467×10^{-5}	3271×10^{-5}	2472×10^{-5}	1959×10^{-5}	1641×10^{-5}	5318×10^{-5}
2	3570×10^{-4}	1816	1450	1004	6726	4465	2994	2043	1439	1058	8159×10^{-6}	2056
3	2437	1450	1721	1385	9610	6435	4272	2867	1965	1403	1058×10^{-5}	2451
4	1651	1004	1385	1677	1355×10^{-4}	9416	6310	4197	2831	1966	1439	3099
5	1129	6726×10^{-5}	9610×10^{-5}	1355	1658	1343×10^{-4}	9343	6276	4197	2867	2043	4089
6	7845×10^{-5}	4466	6435	9416×10^{-5}	1343	1650	1340×10^{-4}	9343	6310	4272	2994	5582
7	5582	2994	4272	6310	9343×10^{-5}	1340	1650	1343×10^{-4}	9416	6435	4466	7845
8	4089	2043	2867	4197	6276	9343×10^{-5}	1343	1658	1355×10^{-4}	9610	6726	1129×10^{-4}
9	3099	1439	1966	2831	4197	6310	9416×10^{-5}	1355	1677	1385×10^{-4}	1004×10^{-4}	1651
10	2451	1058	1403	1965	2867	4272	6435	9610×10^{-5}	1385	1721	1450	2437
11	2056	8159×10^{-6}	1058	1439	2043	2994	4465	6726	1004	1450	1816	3570
12	5318	1641×10^{-5}	1959	2472	3271	4467	6273	9028	1321	1950	2857	4287×10^{-5}
						$\alpha = 0.6$						
1	7677×10^{-5}	2436×10^{-4}	1753×10^{-4}	1257×10^{-4}	9085×10^{-5}	6665×10^{-5}	4998×10^{-5}	3848×10^{-5}	3064×10^{-5}	2564×10^{-5}	2276×10^{-5}	5357×10^{-5}
2	3044×10^{-4}	1763	1433	1042	7404	5248	3768	2761	2092	1660	1393	2849
3	2192	1433	1611	1324	9655	6864	4874	3515	2604	2017	1660	3207
4	1571	1042	1324	1533	1270×10^{-4}	9280	6615	4720	3440	2604	2093	3837
5	1136	7404×10^{-5}	9655×10^{-5}	1270	1496	1245×10^{-4}	9130	6543	4719	3515	2761	4811
6	8335×10^{-5}	5249	6865	9280×10^{-5}	1245	1481	1238×10^{-4}	9130	6614	4874	3768	6246
7	6246	3768	4874	6614	9130×10^{-5}	1238	1481	1245×10^{-4}	9280	6865	5249	8335
8	4811	2761	3515	4719	6543	9130×10^{-5}	1245	1496	1270×10^{-4}	9655	7404	1136×10^{-4}
9	3837	2093	2604	3440	4720	6615	9280×10^{-5}	1270	1533	1324×10^{-4}	1042×10^{-4}	1571
10	3207	1660	2017	2604	3515	4874	6864	9655×10^{-5}	1324	1611	1433	2192
11	2849	1393	1660	2092	2761	3768	5248	7404	1042	1433	1763	3044
12	5357	2276	2564	3064	3848	4998	6665	9085	1257	1753	2436	7677×10^{-5}
						$\alpha = 0.4$						
1	1009×10^{-4}	1994×10^{-4}	1530×10^{-4}	1173×10^{-4}	9071×10^{-5}	7113×10^{-5}	5687×10^{-5}	4658×10^{-5}	3934×10^{-5}	3465×10^{-5}	3203×10^{-5}	5815×10^{-5}
2	2492	1622	1359	1050	8006	6125	4757	3777	3093	2641	2367	4006
3	1912	1359	1455	1232	9558	7308	5620	4405	3552	2986	2641	4333
4	1466	1050	1232	1360	1163×10^{-4}	9053	6959	5398	4296	3553	3094	4922
5	1134	8006×10^{-5}	9558×10^{-5}	1163	1310	1128×10^{-4}	8835	6853	5398	4405	3777	5823
6	8894×10^{-5}	6126	7309	9053×10^{-5}	1128	1288	1117×10^{-4}	8835	6958	5620	4757	7109
7	7109	4757	5620	6958	8835×10^{-5}	1117	1288	1128×10^{-4}	9053	7309	6126	8894
8	5823	3777	4405	5398	6853	8835×10^{-5}	1128	1310	1163×10^{-4}	9558	8006	1134×10^{-4}
9	4922	3094	3553	4296	5398	6959	9053×10^{-5}	1163	1360	1232×10^{-4}	1050×10^{-4}	1466
10	4333	2641	2986	3552	4405	5620	7308	9558×10^{-5}	1232	1455	1359	1912
11	4006	2367	2641	3093	3777	4757	6125	8006	1050	1359	1622	2492
12	5815	3203	3465	3934	4658	5687	7113	9071	1173	1530	1994	1009
						$\alpha = 0.2$						
1	1120×10^{-4}	1485×10^{-4}	1243×10^{-4}	1044×10^{-4}	8848×10^{-5}	7593×10^{-5}	6621×10^{-5}	5881×10^{-5}	5339×10^{-5}	4978×10^{-5}	4775×10^{-5}	7029×10^{-5}
2	1856	1345	1186	9979×10^{-5}	8372	7080	6080	5320	4764	4386	4157	5970
3	1554	1186	1218	1083×10^{-4}	9162	7731	6594	5727	5090	4653	4386	6224
4	1305	9980×10^{-5}	1083	1136	1019×10^{-4}	8675	7380	6365	5613	5090	4765	6677
5	1106	8372	9162×10^{-5}	1019	1088	9844	8450	7269	6365	5727	5320	7352
6	9493×10^{-5}	7081	7731	8675×10^{-5}	9844×10^{-5}	1065×10^{-4}	9733	8450	7380	6594	6080	8276
7	8276	6080	6594	7380	8450	9733×10^{-5}	1065×10^{-4}	9844	8675	7731	7081	9493
8	7352	5320	5727	6365	7269	8450	9844×10^{-5}	1088×10^{-4}	1019×10^{-4}	9162	8372	1106×10^{-4}
9	6677	4765	5090	5613	6365	7380	8675	1019	1136	1083×10^{-4}	9980	1305
10	6224	4386	4653	5090	5727	6594	7731	9162	1083×10^{-5}	1218	1186×10^{-4}	1554
11	5970	4157	4386	4764	5320	6080	7080	8372	9979×10^{-5}	1186	1345	1856
12	7029	4775	4978	5339	5881	6621	7593	8848	1044×10^{-4}	1243	1485	1120

TABLE II.- NET RADIATION FACTORS FOR HONEYCOMB-CORE PANELS - Continued

(c) $\lambda = 3$

n	$G_{n,m}$ at -											
	m = 1	m = 2	m = 3	m = 4	m = 5	m = 6	m = 7	m = 8	m = 9	m = 10	m = 11	m = 12
						$\alpha = 1.0$						
1	0	4464×10^{-4}	2330×10^{-4}	1222×10^{-4}	6730×10^{-5}	3940×10^{-5}	2450×10^{-5}	1610×10^{-5}	1100×10^{-5}	7900×10^{-6}	5800×10^{-6}	2630×10^{-5}
2	3720×10^{-4}	2555	1778	9230×10^{-5}	4580	2320	1240	7000×10^{-6}	4200×10^{-6}	2600	1700	4800×10^{-6}
3	1942	1778	2555	1778×10^{-4}	9230	4580	2320	1240×10^{-5}	7000	4200	2600	6600
4	1018	9230×10^{-5}	1778	2555	1778×10^{-4}	9230	4580	2320	1240×10^{-5}	7000	4200	9200
5	5600×10^{-5}	4580	9230×10^{-5}	1778	2555	1778×10^{-4}	9230	4580	2320	1240×10^{-5}	7000	1340×10^{-5}
6	3280	2320	4580	9230×10^{-5}	1778	2555	1778×10^{-4}	9230	4580	2320	1240×10^{-5}	2040
7	2040	1240	2320	4580	9230×10^{-5}	1778	2555	1778×10^{-4}	9230	4580	2320	3280
8	1340	7000×10^{-6}	1240	2320	4580	9230×10^{-5}	1778	2555	1778×10^{-4}	9230	4580	5600
9	9200×10^{-6}	4200	7000×10^{-6}	1240	2320	4580	9230×10^{-5}	1778	2555	1778×10^{-4}	9230	1018×10^{-4}
10	6600	2600	4200	7000×10^{-6}	1240	2320	4580	9230×10^{-5}	1778	2555	1778×10^{-4}	1942
11	4800	1700	2600	4200	7000×10^{-6}	1240	2320	4580	9230×10^{-5}	1778	2555	3720
12	2630×10^{-5}	5800	7900	1100×10^{-5}	1610×10^{-5}	2450	3940	6730	1222×10^{-4}	2330	4464	0
						$\alpha = 0.8$						
1	4168×10^{-5}	3920×10^{-4}	2199×10^{-4}	1240×10^{-4}	7264×10^{-5}	4452×10^{-5}	2858×10^{-5}	1926×10^{-5}	1362×10^{-5}	1041×10^{-5}	8799×10^{-6}	2427×10^{-5}
2	3267×10^{-4}	2556	1808	1009	5467	3028	1752	1061	6780×10^{-6}	4593×10^{-6}	3452	7305×10^{-6}
3	1833	1808	2402	1722	9605	5186	2860	1649	9992	6487	4596	8690
4	1033	1009	1722	2354	1695×10^{-4}	9450	5095	2807	1624×10^{-5}	9993	6784	1137×10^{-5}
5	6046×10^{-5}	5466×10^{-5}	9604×10^{-5}	1695	2339	1686×10^{-4}	9404	5074	2807	1649×10^{-5}	1061×10^{-5}	1603
6	3706	3027	5186	9450×10^{-5}	1686	2335	1684×10^{-4}	9404	5095	2860	1752	2380
7	2380	1752	2860	5095	9404 $\times 10^{-5}$	1684	2335	1686×10^{-4}	9450	5186	3027	3706
8	1603	1061	1649	2807	5074	9404 $\times 10^{-5}$	1686	2339	1695×10^{-4}	9604	5466	6046
9	1137	6784×10^{-6}	9993×10^{-6}	1624	2807	5095	9450×10^{-5}	1695	2354	1722×10^{-4}	1009×10^{-4}	1033×10^{-4}
10	8690×10^{-6}	4596	6487	9992×10^{-6}	1649	2860	5186	9605×10^{-5}	1722	2402	1808	1833
11	7305	3452	4593	6780	1061	1752	3028	5467	1009	1808	2556	3267
12	2427×10^{-5}	8799	1041×10^{-5}	1362×10^{-5}	1926	2858	4452	7264	1240	2199	3920	4168×10^{-5}
						$\alpha = 0.6$						
1	7442×10^{-5}	3371×10^{-4}	2050×10^{-4}	1254×10^{-4}	7890×10^{-5}	5128×10^{-5}	3452×10^{-5}	2420×10^{-5}	1783×10^{-5}	1427×10^{-5}	1277×10^{-5}	2378×10^{-5}
2	2809×10^{-4}	2473	1801	1090	6484	3937	2475	1616	1108	8133×10^{-6}	6679×10^{-6}	1062
3	1709	1801	2217	1646	9955	5898	3567	2240	1473	1040×10^{-5}	8138	1190
4	1045	1090	1645	2123	1589×10^{-4}	9605	5682	3439	2178	1473	1108×10^{-5}	1488
5	6569×10^{-5}	6483×10^{-5}	9954×10^{-5}	1589	2089	1568×10^{-4}	9489	5628	3439	2240	1615	2015
6	4271	3937	5897	9605×10^{-5}	1568	2077	1563×10^{-4}	9489	5682	3566	2474	2875
7	2875	2474	3566	5682	9489×10^{-5}	1563	2077	1568×10^{-4}	9605	5897	3937	4271
8	2015	1615	2240	3439	5628	9489×10^{-5}	1568	2089	1589×10^{-4}	9954	6483	6569
9	1488	1108	1473	2178	3439	5682	9605×10^{-5}	1589	2123	1645×10^{-4}	1090×10^{-4}	1045×10^{-4}
10	1190	8138×10^{-6}	1040	1473	2240	3567	5898	9955×10^{-5}	1646	2217	1801	1709
11	1062	6679	8133×10^{-6}	1108	1616	2475	3937	6484	1090	1801	2473	2809
12	2378	1277×10^{-5}	1427×10^{-5}	1783	2420	3452	5128	7890	1254	2050	3371	7442×10^{-5}
						$\alpha = 0.4$						
1	9679×10^{-5}	2776×10^{-4}	1857×10^{-4}	1250×10^{-4}	8580×10^{-5}	6028×10^{-5}	4348×10^{-5}	3242×10^{-5}	2528×10^{-5}	2116×10^{-5}	1945×10^{-5}	2600×10^{-5}
2	2314×10^{-4}	2272	1730	1152	7618	5130	3549	2536	1893	1507	1318	1619
3	1548	1730	1976	1533	1021×10^{-4}	6737	4535	3155	2291	1776	1508	1764
4	1041	1152	1533	1845	1447	9642	6364	4308	3044	2292	1894	2108
5	7145×10^{-5}	7616×10^{-5}	1021	1447	1789	1411×10^{-4}	9428	6262	4307	3155	2535	2700
6	5020	5129	6736×10^{-5}	9641×10^{-5}	1411	1768	1402×10^{-4}	9428	6364	4535	3549	3622
7	3622	3549	4535	6364	9428 $\times 10^{-5}$	1402	1768	1411×10^{-4}	9641	6736	5129	5020
8	2700	2535	3155	4307	6262	9428 $\times 10^{-5}$	1411	1789	1447×10^{-4}	1021×10^{-4}	7616	7145
9	2108	1894	2292	3044	4308	6364	9642×10^{-5}	1447	1845	1533	1152×10^{-4}	1041×10^{-4}
10	1764	1508	1776	2291	3155	4535	6737	1021	1533	1976	1730	1548
11	1619	1318	1507	1893	2536	3549	5130	7618×10^{-5}	1152	1730	2272	2314
12	2600	1945	2116	2528	3242	4348	6028	8580	1250	1857	2776	9679×10^{-5}
						$\alpha = 0.2$						
1	1035×10^{-4}	2049×10^{-4}	1552×10^{-4}	1183×10^{-4}	9159×10^{-5}	7208×10^{-5}	5788×10^{-5}	4771×10^{-5}	4068×10^{-5}	3634×10^{-5}	3435×10^{-5}	3491×10^{-5}
2	1707	1857	1520	1149	8698	6695	5269	4259	3564	3123	2900	2861
3	1293	1520	1613	1339	1014×10^{-4}	7699	5967	4757	3930	3403	3124	3029
4	9860×10^{-5}	1149	1339	1479	1240	9429	7203	5650	4600	3930	3564	3390
5	7628	8696×10^{-5}	1014	1240	1409	1192×10^{-4}	9124	7054	5650	4756	4258	3974
6	6004	6694	7698×10^{-5}	9428×10^{-5}	1192	1378	1177×10^{-4}	9124	7202	5966	5268	4822
7	4822	5268	5966	7202	9124 $\times 10^{-5}$	1177	1378	1192×10^{-4}	9428	7698	6694	6004
8	3974	4258	4756	5650	7054	9124 $\times 10^{-5}$	1192	1409	1240×10^{-4}	1014×10^{-4}	8696	7628
9	3390	3564	3930	4600	5650	7203	9429 $\times 10^{-5}$	1240	1479	1339	1149×10^{-4}	9860
10	3029	3124	3403	3930	4757	5967	7699	1014	1339	1613	1520	1293×10^{-4}
11	2861	2900	3123	3564	4259	5269	6695	8698×10^{-5}	1149	1520	1857	1707
12	3491	3435	3634	4068	4771	5788	7208	9159	1183	1552	2049	1035

TABLE II.- NET RADIATION FACTORS FOR HONEYCOMB-CORE PANELS - Continued

(d) $\lambda = 5$

n	$G_{n,m}$ at -											
	m = 1	m = 2	m = 3	m = 4	m = 5	m = 6	m = 7	m = 8	m = 9	m = 10	m = 11	m = 12
						$\alpha = 1.0$						
1	0	6180×10^{-4}	2104×10^{-4}	7990×10^{-5}	3590×10^{-5}	1860×10^{-5}	1080×10^{-5}	6700×10^{-6}	4500×10^{-6}	3100×10^{-6}	2200×10^{-6}	9800×10^{-6}
2	3090×10^{-4}	3820	2038	6520	2200	8600×10^{-6}	3900×10^{-6}	2000	1100	7000×10^{-7}	4000×10^{-7}	1100
3	1052	2038	3820	2038 $\times 10^{-4}$	6520	2200×10^{-5}	8600	3900	2000	1100×10^{-6}	7000	1600
4	4000×10^{-5}	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	6520	2200×10^{-5}	8600	3900	2000	1100×10^{-6}	2200
5	1800	2200	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	6520	2200 $\times 10^{-5}$	8600	3900	2000	3400
6	9300×10^{-6}	8600×10^{-6}	2200	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	6520	2200 $\times 10^{-5}$	8600	3900	5400
7	5400	3900	8600×10^{-6}	2200	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	6520	2200 $\times 10^{-5}$	8600	9300
8	3400	2000	3900	8600×10^{-6}	2200	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	6520	2200 $\times 10^{-5}$	1800×10^{-5}
9	2200	1100	2000	3900	8600×10^{-6}	2200	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	6520	4000
10	1600	7000×10^{-7}	1100	2000	3900	8600×10^{-6}	2200	6520×10^{-5}	2038	3820	2038 $\times 10^{-4}$	1052×10^{-4}
11	1100	4000	7000×10^{-7}	1100	2000	3900	8600×10^{-6}	2200	6520×10^{-5}	2038	3820	3090
12	9800	2200×10^{-6}	3100×10^{-6}	4500	6700	1080×10^{-5}	1860×10^{-5}	3590	7990	2104	6180	0
						$\alpha = 0.8$						
1	3951×10^{-5}	5515×10^{-4}	2131×10^{-4}	8935×10^{-5}	4221×10^{-5}	2217×10^{-5}	1279×10^{-5}	7898×10^{-6}	5320×10^{-6}	3916×10^{-6}	3522×10^{-6}	8594×10^{-6}
2	2758×10^{-4}	3783	2097	7739	3007	1302	6290×10^{-6}	3343	1922	1265	9313×10^{-7}	1763
3	1065	2097	3551	2007×10^{-4}	7363	2829	1210×10^{-5}	5762	3037	1763	1271×10^{-6}	2001
4	4472×10^{-5}	7740×10^{-5}	2007	3516	1993×10^{-4}	7296	2794	1191×10^{-5}	5669	3034	1916	2620
5	2115	3007	7363×10^{-5}	1993	3510	1990×10^{-4}	7282	2788	1191×10^{-5}	5764	3349	3992
6	1109	1302	2829	7296×10^{-5}	1990	3509	1990×10^{-4}	7282	2794	1210×10^{-5}	6291	6399
7	6399×10^{-6}	6291×10^{-6}	1210	2794	7282×10^{-5}	1990	3509	1990×10^{-4}	7296	2829	1302×10^{-5}	1109×10^{-5}
8	3992	3349	5764×10^{-6}	1191	2788	7282×10^{-5}	1990	3510	1993×10^{-4}	7363	3007	2115
9	2620	1916	3034	5669×10^{-6}	1191	2794	7296×10^{-5}	1993	3516	2007×10^{-4}	7740	4472
10	2001	1271	1763	3037	5762×10^{-6}	1210	2829	7363×10^{-5}	2007	3551	2097×10^{-4}	1065×10^{-4}
11	1763	9313×10^{-7}	1265	1922	3343	6290×10^{-6}	1302	3007	7739×10^{-5}	2097	3783	2758
12	8594	3522×10^{-6}	3916	5320	7898	1279×10^{-5}	2217	4221	8935	2131	5515	3951×10^{-5}
						$\alpha = 0.6$						
1	7086×10^{-5}	4828×10^{-4}	2142×10^{-4}	1008×10^{-4}	5131×10^{-5}	2806×10^{-5}	1644×10^{-5}	1022×10^{-5}	6928×10^{-6}	5297×10^{-6}	5126×10^{-6}	7828×10^{-6}
2	2414×10^{-4}	3649	2138	9181×10^{-5}	4121	1995	1040	5807×10^{-6}	3494	2393	1986	2566
3	1071	2138	3236	1955×10^{-4}	8320	3682	1757	9030	5024	3104	2404	2684
4	5043×10^{-5}	9183×10^{-5}	1955	3155	1917×10^{-4}	8128	3580	1701×10^{-5}	8763	5018	3485	3435
5	2570	4122	8320×10^{-5}	1917	3137	1908×10^{-4}	8084	3561	1701×10^{-5}	9034	5819	5148
6	1404	1995	3683	8128×10^{-5}	1908	3133	1906×10^{-4}	8084	3580	1757×10^{-5}	1040×10^{-5}	8224
7	8224×10^{-6}	1040	1757	3580	8084×10^{-5}	1906	3133	1908×10^{-4}	8128	3683	1995	1404×10^{-5}
8	5148	5819×10^{-6}	9034×10^{-6}	1701	3561	8084×10^{-5}	1908	3137	1917×10^{-4}	8320	4122	2570
9	3435	3485	5018	8763×10^{-6}	1701	3580	8128×10^{-5}	1917	3155	1955×10^{-4}	9183	5043
10	2684	2404	3104	5024	9030×10^{-6}	1757	3682	8320×10^{-5}	1955	3236	2138×10^{-4}	1071×10^{-4}
11	2566	1986	2393	3494	5807	1040	1995	4121	9181×10^{-5}	2138	3649	2414
12	7828	5126	5297	6928	1022×10^{-5}	1644	2806	5131	1008×10^{-4}	2142	4828	7086×10^{-5}
						$\alpha = 0.4$						
1	9240×10^{-5}	4059×10^{-4}	2110×10^{-4}	1141×10^{-4}	6463×10^{-5}	3820×10^{-5}	2358×10^{-5}	1524×10^{-5}	1058×10^{-5}	8265×10^{-6}	7913×10^{-6}	7879×10^{-6}
2	2030×10^{-4}	3365	2132	1084	5708	3152	1822	1104	7113×10^{-6}	5126	4444	3961
3	1055	2132	2848	1863	9393	4888	2673	1536	9379	6310	5141	4162
4	5707×10^{-5}	1085	1863	2708	1788×10^{-4}	8973	4648	2538	1472×10^{-5}	9370	7103	5274
5	3236	5710×10^{-5}	9394×10^{-5}	1788	2668	1766×10^{-4}	8856	4595	2538	1537×10^{-5}	1105×10^{-5}	7650
6	1911	3152	4888	8974×10^{-5}	1766	2657	1762×10^{-4}	8856	4648	2673	1822	1180×10^{-5}
7	1180	1822	2673	4648	8856×10^{-5}	1762	2657	1766×10^{-4}	8974	4888	3152	1911
8	7650×10^{-6}	1105	1537	2538	4595	8856×10^{-5}	1766	2668	1788×10^{-4}	9394	5710	3236
9	5274	7103×10^{-6}	9370×10^{-6}	1472	2538	4648	8973×10^{-5}	1788	2708	1863×10^{-4}	1085×10^{-4}	5707
10	4162	5141	6310	9379×10^{-6}	1536	2673	4888	9393×10^{-5}	1863	2848	2132	1055×10^{-4}
11	3961	4444	5126	7113	1104	1822	3152	5708	1084	2132	3365	2030
12	7879	7913	8265	1058×10^{-5}	1524	2358	3820	6463	1141	2110	4059	9240×10^{-5}
						$\alpha = 0.2$						
1	9801×10^{-5}	3058×10^{-4}	1941×10^{-4}	1260×10^{-4}	8380×10^{-5}	5692×10^{-5}	3962×10^{-5}	2846×10^{-5}	2151×10^{-5}	1765×10^{-5}	1640×10^{-5}	1087×10^{-5}
2	1529×10^{-4}	2775	1980	1242	7970	5255	3559	2488	1824	1447	1296	8208×10^{-6}
3	9708×10^{-5}	1980	2296	1676	1046×10^{-4}	6683	4407	3007	2152	1661	1449	8847
4	6305	1242	1676	2105	1553	9663	6177	4102	2861	2150	1823	1075×10^{-5}
5	4193	7973×10^{-5}	1046	1553	2027	1505×10^{-4}	9378	6043	4104	3008	2490	1426
6	2848	5257	6684×10^{-5}	9663×10^{-5}	1505	1999	1492×10^{-4}	9378	6177	4408	3560	1983
7	1983	3560	4408	6177	9378×10^{-5}	1492	1999	1505×10^{-4}	9663	6684	5257	2848
8	1426	2490	3008	4104	6043	9378×10^{-5}	1505	2027	1553×10^{-4}	1046×10^{-4}	7973	4193
9	1075	1823	2150	2861	4102	6177	9663×10^{-5}	1553	2105	1676	1242×10^{-4}	6305
10	8847×10^{-6}	1449	1661	2152	3007	4407	6683	1046	1676	2296	1980	9708
11	8208	1296	1447	1824	2488	3559	5255	7970×10^{-5}	1242	1980	2775	1529×10^{-4}
12	1087×10^{-5}	1640	1765	2151	2846	3962	5692	8380	1260	1941	3058	9801×10^{-5}

TABLE II.- NET RADIATION FACTORS FOR HONEYCOMB-CORE PANELS - Concluded

(e) $\lambda = 10$

n	$G_{n,m}$ at -											
	m = 1	m = 2	m = 3	m = 4	m = 5	m = 6	m = 7	m = 8	m = 9	m = 10	m = 11	m = 12
						$\alpha = 1.0$						
1	0	8284×10^{-4}	1158×10^{-4}	2930×10^{-5}	1120×10^{-5}	5400×10^{-6}	3000×10^{-6}	1800×10^{-6}	1200×10^{-6}	8000×10^{-7}	6000×10^{-7}	2500×10^{-6}
2	2071×10^{-4}	5858	1781	2160	4600×10^{-6}	1400	6000×10^{-7}	3000×10^{-7}	2000×10^{-7}	1000	0	1000×10^{-7}
3	2900×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	4600	1400×10^{-6}	6000	3000	2000	1000	2000
4	7300×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	4600	1400×10^{-6}	6000	3000	2000	3000
5	2800	4600×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	4600	1400×10^{-6}	6000	3000	4000
6	1300	1400	4600×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	4600	1400×10^{-6}	6000	7000
7	7000×10^{-7}	6000×10^{-7}	1400	4600×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	4600	1400×10^{-6}	1300×10^{-6}
8	4000	3000	6000×10^{-7}	1400	4600×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	4600	2800
9	3000	2000	3000	6000×10^{-7}	1400	4600×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2160×10^{-5}	7300
10	2000	1000	2000	3000	6000×10^{-7}	1400	4600×10^{-6}	2160×10^{-5}	1781	5858	1781×10^{-4}	2900×10^{-5}
11	1000	0	1000	2000	3000	6000×10^{-7}	1400	4600×10^{-6}	2160×10^{-5}	1781	5858	2071×10^{-4}
12	2500×10^{-6}	6000	8000	1200×10^{-6}	1800×10^{-6}	3000×10^{-6}	5400	1120×10^{-5}	2930	1158	8284	0
						$\alpha = 0.8$						
1	3245×10^{-5}	7625×10^{-4}	1381×10^{-4}	3665×10^{-5}	1345×10^{-5}	6188×10^{-6}	3331×10^{-6}	1969×10^{-6}	1308×10^{-6}	9215×10^{-7}	9938×10^{-7}	2092×10^{-6}
2	1906×10^{-4}	5745	1909	3167	7564×10^{-6}	2386	1000	4987×10^{-7}	3151×10^{-7}	1755	7999×10^{-8}	2026×10^{-7}
3	3457×10^{-5}	1909	5471	1859×10^{-4}	3033×10^{-5}	7067	2157	8767	4286	2726	1767×10^{-7}	2281
4	9140×10^{-6}	3167×10^{-5}	1859	5462	1856×10^{-4}	3025×10^{-5}	7027	2136×10^{-6}	8665	4285	3150	3243
5	3360	7564×10^{-6}	3033×10^{-5}	1856	5461	1856×10^{-4}	3024×10^{-5}	7023	2136×10^{-6}	8750	4898	4441
6	1499	2377	7065×10^{-6}	3025×10^{-5}	1856	5461	1856×10^{-4}	3024×10^{-5}	7027	2155×10^{-6}	9910	7832
7	7832×10^{-7}	9910×10^{-7}	2155	7027×10^{-6}	3024×10^{-5}	1856	5461	1856×10^{-4}	3025×10^{-5}	7065	2377×10^{-6}	1499×10^{-6}
8	4441	4898	8750×10^{-7}	2136	7023×10^{-6}	3024×10^{-5}	1856	5461	1856×10^{-4}	3033×10^{-5}	7564	3360
9	3243	3150	4285	8665×10^{-7}	2136	7027×10^{-6}	3025×10^{-5}	1856	5462	1859×10^{-4}	3167×10^{-5}	9140
10	2281	1767	2726	4286	8767×10^{-7}	2157	7067×10^{-6}	3033×10^{-5}	1859	5471	1909×10^{-4}	3457×10^{-5}
11	2026	7999×10^{-8}	1755	3151	4987	1000	2386	7564×10^{-6}	3167×10^{-5}	1909	5745	1906×10^{-4}
12	2092×10^{-6}	9938×10^{-7}	9215	1308×10^{-6}	1969×10^{-6}	3331	6188	1345×10^{-5}	3665	1381	7625	3245×10^{-5}
						$\alpha = 0.6$						
1	5927×10^{-5}	6906×10^{-4}	1633×10^{-4}	4863×10^{-5}	1794×10^{-5}	7928×10^{-6}	4081×10^{-6}	2343×10^{-6}	1535×10^{-6}	1139×10^{-6}	1396×10^{-6}	1749×10^{-6}
2	1727×10^{-4}	5535	2060	4624	1300	4397	1822	8883×10^{-7}	5302×10^{-7}	3207×10^{-7}	2456×10^{-7}	3077×10^{-7}
3	4087×10^{-5}	2060	4992	1930×10^{-4}	4238	1156×10^{-5}	3757	1494×10^{-6}	7088	4275	3228	2796
4	1214	4623×10^{-5}	1930	4961	1921×10^{-4}	4204	1141×10^{-5}	3684	1459×10^{-6}	7083	5288	3778
5	4480×10^{-6}	1300	4237×10^{-5}	1921	4958	1920×10^{-4}	4200	1140×10^{-5}	3683	1489×10^{-6}	8681	5391
6	1935	4377×10^{-6}	1155	4204×10^{-5}	1920	4958	1920×10^{-4}	4200	1141×10^{-5}	3752	1801×10^{-6}	9705
7	9705×10^{-7}	1801	3752×10^{-6}	1141	4200×10^{-5}	1920	4958	1920×10^{-4}	4204	1155×10^{-5}	4377	1935 x 10^{-6}
8	5391	8681×10^{-7}	1489	3683×10^{-6}	1140	4200×10^{-5}	1920	4958	1921×10^{-4}	4237	1300×10^{-5}	4480
9	3778	5288	7083×10^{-7}	1459	3684×10^{-6}	1141	4204 x 10^{-5}	1921	4961	1930×10^{-4}	4623	1214×10^{-5}
10	2796	3228	4275	7088×10^{-7}	1494	3757×10^{-6}	1156	4238×10^{-5}	1930	4992	2060×10^{-4}	4087
11	3077	2456	3207	5302	8883×10^{-7}	1822	4397×10^{-6}	1300	4624×10^{-5}	2060	5535	1727×10^{-4}
12	1749×10^{-6}	1396×10^{-6}	1139×10^{-6}	1535×10^{-6}	2343×10^{-6}	4081	7928	1794	4863	1633	6906	5927×10^{-5}
						$\alpha = 0.4$						
1	7879×10^{-5}	6044×10^{-4}	1914×10^{-4}	6865×10^{-5}	2761×10^{-5}	1234×10^{-5}	6148×10^{-6}	3391×10^{-6}	2146×10^{-6}	1619×10^{-6}	1933×10^{-6}	1490×10^{-6}
2	1511×10^{-4}	5153	2228	6858	2397	9260×10^{-6}	4008	1941	1096	6933×10^{-7}	6209×10^{-7}	4467×10^{-7}
3	4788×10^{-5}	2228	4371	1979×10^{-4}	5963	2034×10^{-5}	7636	3205	1525	8794	6954	3958
4	1715	6857×10^{-5}	1979	4292	1951×10^{-4}	5849	1983×10^{-5}	7395	3098	1522×10^{-6}	1090×10^{-6}	5256
5	6892×10^{-6}	2396	5962×10^{-5}	1951	4282	1947×10^{-4}	5832	1976×10^{-5}	7391	3193	1905	8020
6	3039	9223×10^{-6}	2032	5849×10^{-5}	1947	4280	1946×10^{-4}	5832	1983×10^{-5}	7623	3968	1487×10^{-6}
7	1487	3968	7623×10^{-6}	1983	5832×10^{-5}	1946	4280	1947×10^{-4}	5849	2032×10^{-5}	9223	3039
8	8020×10^{-7}	1905	3193	7391×10^{-6}	1976	5832×10^{-5}	1947	4282	1951×10^{-4}	5962	2396×10^{-5}	6892
9	5256	1090	1522	3098	7395×10^{-6}	1983	5849×10^{-5}	1951	4292	1979×10^{-4}	6857	1715×10^{-5}
10	3958	6954×10^{-7}	8794×10^{-7}	1525	3205	7636×10^{-6}	2034	5963×10^{-5}	1979	4371	2228×10^{-4}	4788
11	4467	6209	6933	1096	1941	4008	9260×10^{-6}	2397	6858×10^{-5}	2228	5153	1511×10^{-4}
12	1490×10^{-6}	1933×10^{-6}	1619×10^{-6}	2146	3391	6148	1234×10^{-5}	2761	6865	1914	6044	7879×10^{-5}
						$\alpha = 0.2$						
1	8535×10^{-5}	4802×10^{-4}	2168×10^{-4}	1033×10^{-4}	5139×10^{-5}	2653×10^{-5}	1429×10^{-5}	8104×10^{-6}	5025×10^{-6}	3619×10^{-6}	3547×10^{-6}	1534×10^{-6}
2	1201×10^{-4}	4371	2351	1049	4954	2435	1248	6706	3891	2541	2168	8563×10^{-7}
3	5423×10^{-5}	2351	3484	1949	8571	3999	1944	9884	5350	3257	2539	8894
4	2582	1048	1949	3302	1863×10^{-4}	8143	3781	1834×10^{-5}	9406	5342	3872	1236×10^{-6}
5	1283	4952×10^{-5}	8570×10^{-5}	1863×10^{-4}	3261	1843×10^{-4}	8045	3740	1833×10^{-5}	9855	6643	1979
6	6586×10^{-6}	2428	3996	8141×10^{-5}	1843	3252	1839×10^{-4}	8045	3780	1940×10^{-5}	1241×10^{-5}	3520
7	3520	1241	1940	3780	8045×10^{-5}	1839	3252	1843×10^{-4}	8141	3996	2428	6586
8	1979	6643×10^{-6}	9855×10^{-6}	1833	3740	8045×10^{-5}	1843	3261	1863×10^{-4}	8570	4952	1283×10^{-5}
9	1236	3872	5342	9406×10^{-6}	1834	3781	8143×10^{-5}	1863	3302	1949×10^{-4}	1048×10^{-4}	2582
10	8894×10^{-7}	2539	3257	5350	9884×10^{-6}	1944	3999	8571×10^{-5}	1949	3484	2351	5423
11	8563	2168	2541	3891	6706	1248	2435	4954	1049	2351	4371	1201×10^{-4}
12	1534×10^{-6}	3547	3619	5025	8104	1429	2653	5139	1033	2168	4802	8535×10^{-5}

TABLE III.- EFFECT OF CORE EMISSIVITY IN HONEYCOMB-CORE PANELS

ϵ_1	$\epsilon_2 - \epsilon_{11}$	ϵ_{12}	$\frac{k_e A_1}{k \Delta A}$ for -	
			$\bar{T}_1 = 1.6$; $\bar{T}_{12} = 0.8$	$\bar{T}_1 = 2.0$; $\bar{T}_{12} = 1.8$
1.0	1.0	1.0	3.996	11.347
1.0	.8	1.0	3.972	11.311
1.0	.6	1.0	3.943	11.265
1.0	.4	1.0	3.904	11.201
1.0	.2	1.0	3.848	11.101
.8	1.0	.8	3.710	10.147
.8	.8	.8	3.675	10.090
.8	.6	.8	3.630	10.014
.8	.4	.8	3.570	9.909
.8	.2	.8	3.483	9.744
.6	1.0	.6	3.414	8.875
.6	.8	.6	3.364	8.788
.6	.6	.6	3.300	8.674
.6	.4	.6	3.214	8.513
.6	.2	.6	3.085	8.258
.4	1.0	.4	3.106	7.524
.4	.8	.4	3.039	7.399
.4	.6	.4	2.952	7.234
.4	.4	.4	2.832	7.001
.4	.2	.4	2.651	6.625
.2	1.0	.2	2.785	6.084
.2	.8	.2	2.696	5.912
.2	.6	.2	2.581	5.683
.2	.4	.2	2.421	5.355
.2	.2	.2	2.174	4.821

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TABLE IV.- CALCULATED EFFECTIVE THERMAL CONDUCTIVITY RATIOS FOR CORRUGATED-CORE PANELS

$\bar{X}$	$\bar{Y}$	$\bar{T}_{H,av}$	$\bar{T}_{C,av}$	$\frac{k_e}{k_w \bar{Y}}$ for -				
				$\epsilon = 1.0$	$\epsilon = 0.8$	$\epsilon = 0.6$	$\epsilon = 0.4$	$\epsilon = 0.2$
0.1	0.75	0.5	0.4	7035×10^{-4}	6353×10^{-4}	5797×10^{-4}	5324×10^{-4}	4909×10^{-4}
		.7	.6	1194×10^{-3}	993×10^{-3}	8284	6891	5663
		1.0	.8	2389	1863	1434×10^{-3}	1071×10^{-3}	7516
		1.5	1.3	7377	5466	3928	2641	1520×10^{-3}
		2.0	1.8	1724×10^{-2}	1254×10^{-2}	877×10^{-2}	5652	2982
		2.5	2.3	3376	2434	1679	1058×10^{-2}	5335
		3.0	2.8	5875	4215	2888	1798	881×10^{-2}
		4.0	3.8	1413×10^{-1}	1009×10^{-1}	6872	4225	2012
.1	.50	.5	.4	8743×10^{-4}	7736×10^{-4}	6904×10^{-4}	6194×10^{-4}	5563×10^{-4}
		.7	.6	1607×10^{-3}	1310×10^{-3}	1065×10^{-3}	8576	6723
		1.0	.8	3378	2601	1969	1432×10^{-3}	954×10^{-3}
		1.5	1.3	1074×10^{-2}	7913	5641	3747	2099
		2.0	1.8	2533	1835×10^{-2}	1277×10^{-2}	8171	4245
		2.5	2.3	4979	3581	2463	1544×10^{-2}	7698
		3.0	2.8	8680	6217	4250	2694	1281×10^{-2}
		4.0	3.8	2091×10^{-1}	1493×10^{-1}	1015×10^{-1}	6226	2952
.1	.25	.5	.4	1306×10^{-3}	1108×10^{-3}	944×10^{-3}	8023×10^{-4}	6743×10^{-4}
		.7	.6	2747	2166	1690	1282×10^{-3}	912×10^{-3}
		1.0	.8	6186	4670	3442	2404	1475
		1.5	1.3	2050×10^{-2}	1495×10^{-2}	1051×10^{-2}	6839	3677
		2.0	1.8	4903	3531	2436	1536×10^{-2}	7765
		2.5	2.3	970×10^{-1}	6946	4750	2949	1440×10^{-2}
		3.0	2.8	1696	1212×10^{-1}	8248	5079	2432
		4.0	3.8	4098	2919	1980×10^{-1}	1211×10^{-1}	5692
.05	.75	.5	.4	7485×10^{-4}	6768×10^{-4}	6183×10^{-4}	5686×10^{-4}	5248×10^{-4}
		.7	.6	1265×10^{-3}	1053×10^{-3}	8802	7335	6044
		1.0	.8	2518	1965	1516×10^{-3}	1136×10^{-3}	7994
		1.5	1.3	7738	5732	4121	2777	1605×10^{-3}
		2.0	1.8	1805×10^{-2}	1311×10^{-2}	9164	5911	3131
		2.5	2.3	3534	2540	1751×10^{-2}	1104×10^{-2}	5577
		3.0	2.8	6147	4396	3006	1870	9181
		4.0	3.8	1478×10^{-1}	1053×10^{-1}	7145	4386	2089×10^{-2}
.05	.50	.5	.4	9269×10^{-4}	8203×10^{-4}	7327×10^{-4}	6578×10^{-4}	5911×10^{-4}
		.7	.6	1700×10^{-3}	1386×10^{-3}	1129×10^{-3}	9092	7136
		1.0	.8	3564	2744	2078	1513×10^{-3}	1011×10^{-3}
		1.5	1.3	1130×10^{-2}	8319	5930	3942	2213
		2.0	1.8	2664	1927×10^{-2}	1339×10^{-2}	8566	4459
		2.5	2.3	5237	3755	2579	1616×10^{-2}	8063
		3.0	2.8	9130	6519	4447	2753	1339×10^{-2}
		4.0	3.8	2200×10^{-1}	1564×10^{-1}	1061×10^{-1}	6498	3079
.05	.25	.5	.4	1390×10^{-3}	1179×10^{-3}	1005×10^{-3}	8550×10^{-4}	7193×10^{-4}
		.7	.6	2914	2298	1795	1363×10^{-3}	971×10^{-3}
		1.0	.8	6550	4943	3646	2550	1568
		1.5	1.3	2170×10^{-2}	1579×10^{-2}	1110×10^{-2}	7222	3891
		2.0	1.8	5195	3732	2570	1619×10^{-2}	8192
		2.5	2.3	1028×10^{-1}	7345	5013	3107	1518×10^{-2}
		3.0	2.8	1800	1281×10^{-1}	8704	5351	2560
		4.0	3.8	4349	3089	2090×10^{-1}	1276×10^{-1}	5989
.02	.75	.5	.4	7789×10^{-4}	7050×10^{-4}	6445×10^{-4}	5930×10^{-4}	5477×10^{-4}
		.7	.6	1312×10^{-3}	1093×10^{-3}	9151	7637	6300
		1.0	.8	2605	2035	1572×10^{-3}	1179×10^{-3}	8318
		1.5	1.3	7986	5914	4254	2870	1664×10^{-3}
		2.0	1.8	1862×10^{-2}	1350×10^{-2}	9435	6090	3232
		2.5	2.3	3643	2614	1800×10^{-2}	1135×10^{-2}	5743
		3.0	2.8	6335	4522	3089	1920	9437
		4.0	3.8	1523×10^{-1}	1081×10^{-1}	7335	4498	2143×10^{-2}
.02	.50	.5	.4	9649×10^{-4}	8545×10^{-4}	7639×10^{-4}	6862×10^{-4}	6171×10^{-4}
		.7	.6	1765×10^{-3}	1440×10^{-3}	1174×10^{-3}	9468	7442
		1.0	.8	3692	2845	2156	1573×10^{-3}	1052×10^{-3}
		1.5	1.3	1169×10^{-2}	8599	6130	4079	2295
		2.0	1.8	2754	1989×10^{-2}	1382×10^{-2}	8841	4609
		2.5	2.3	5415	3876	2659	1665×10^{-2}	8318
		3.0	2.8	9441	6728	4582	2836	1380×10^{-2}
		4.0	3.8	2275×10^{-1}	1614×10^{-1}	1093×10^{-1}	6687	3167
.02	.25	.5	.4	1445×10^{-3}	1226×10^{-3}	1046×10^{-3}	8904×10^{-4}	7494×10^{-4}
		.7	.6	3026	2388	1866	1418×10^{-3}	1011×10^{-3}
		1.0	.8	6796	5129	3784	2648	1631
		1.5	1.3	2251×10^{-2}	1638×10^{-2}	1149×10^{-2}	7482	4036
		2.0	1.8	5395	3870	2662	1677×10^{-2}	8481
		2.5	2.3	1069×10^{-1}	7619	5192	3216	1570×10^{-2}
		3.0	2.8	1871	1329×10^{-1}	9017	5536	2647
		4.0	3.8	4522	3205	2166×10^{-1}	1320×10^{-1}	6191

TABLE V.- NET RADIATION FACTORS FOR CORRUGATED-CORE PANELS

n	$G_{n,m}$ at -													
	m = 1	m = 2	m = 3	m = 5	m = 6	m = 7	m = 8	m = 8a	m = 7a	m = 6a	m = 5a	m = 3a	m = 2a	m = 1a
							$\alpha = 1.0$							
1	0	0	0	3395×10^{-5}	1560×10^{-4}	2132×10^{-4}	1468×10^{-4}	1607×10^{-4}	1726×10^{-4}	9921×10^{-5}	1798×10^{-5}	0	0	0
2	0	0	0	1092×10^{-4}	2993	1865	8801×10^{-5}	1407	1114	5188	1303	0	0	0
3	0	0	0	5775	1690	4476×10^{-5}	1876	9516×10^{-5}	6085×10^{-5}	2747	6484×10^{-6}	0	0	0
5	1921×10^{-5}	1236×10^{-4}	6534×10^{-4}	0	0	0	0	1959	4712	5461	5026×10^{-5}	7335×10^{-6}	1474×10^{-5}	1017×10^{-5}
6	8825	3386	1912	0	0	0	0	3689	7454	7003	5461	3108×10^{-5}	5870	5612
7	1206×10^{-4}	2110	5065×10^{-5}	0	0	0	0	8907	1148×10^{-4}	7454	4712	6884	1261×10^{-4}	9766
8	8303×10^{-5}	9957×10^{-5}	2122	0	0	0	0	2929 x 10^{-4}	8907×10^{-5}	3689	1959	1077×10^{-4}	1592	9088
8a	1017	1474	7335×10^{-6}	5026×10^{-5}	5461×10^{-5}	4712	1959	0	0	0	0	6534	1236	1921
7a	5612	5870	3108×10^{-5}	5461	7003	7454	3689	0	0	0	0	1912	3386	8825
6a	9766	1261×10^{-4}	6884	4712	7454	1148×10^{-4}	8907	0	0	0	0	5065×10^{-5}	2110	1206×10^{-4}
5a	9088	1592	1077×10^{-4}	1959	3689	8907×10^{-5}	2929×10^{-4}	0	0	0	0	2122	9957×10^{-5}	8303×10^{-5}
3a	0	0	0	1798	9921	1726 x 10^{-4}	1607	1468	2132×10^{-4}	1560×10^{-4}	3395	0	0	0
2a	0	0	0	1303	5188	1114	1407	8801×10^{-5}	1865	2993	1092×10^{-4}	0	0	0
1a	0	0	0	6484×10^{-6}	2747	6085×10^{-5}	9516×10^{-5}	1876	4476×10^{-5}	1690	5775	0	0	0
							$\alpha = 0.8$							
1	1561×10^{-5}	2955×10^{-5}	1756×10^{-5}	3324×10^{-5}	1331×10^{-4}	1813×10^{-4}	1318×10^{-4}	1432×10^{-4}	1501×10^{-4}	8851×10^{-5}	2090×10^{-5}	1445×10^{-5}	2612×10^{-5}	1514×10^{-5}
2	1477	3454	2809	9381	2468	1579	8237×10^{-5}	1251	1018	5178	1792	1150	2051	1306
3	8779×10^{-6}	2809	7050	4723×10^{-4}	1419	4191×10^{-5}	2297	8397×10^{-5}	5920×10^{-5}	3190	1322	6551×10^{-6}	1150	7226×10^{-6}
5	1880×10^{-5}	1061×10^{-4}	5343×10^{-4}	6588×10^{-5}	2771×10^{-5}	1348	8948×10^{-6}	3142	5011	5156	4463	1496	2027	1182×10^{-5}
6	7527	2792	1606	2771	2930	2264	1651×10^{-5}	4718	7656	6875	5156	3610	5898	3007
7	1026×10^{-4}	1786	4741×10^{-5}	1348	2264	2346	2140	8714	1098×10^{-4}	7656	5011	6697	1152×10^{-4}	8489
8	7453×10^{-5}	9319×10^{-5}	2598	8948×10^{-6}	1651	2140	2883	2473×10^{-4}	8714×10^{-5}	4718	3142	9500	1416	8101
8a	1182	2027	1496	4463×10^{-5}	5156	5011	3142	8948×10^{-6}	1348	2771	6588	5343×10^{-4}	1061	1880
7a	5007	5858	3610	5156	6875	7656	4718	1651×10^{-5}	2264	2930	2771	1606	2792	7527
6a	8489	1152×10^{-4}	6697	5011	7656	1098×10^{-4}	8714	2140	2346	2264	1348	4741×10^{-5}	1786	1026×10^{-4}
5a	8101	1416	9500	3142	4718	8714×10^{-5}	2473×10^{-4}	2883	2140	1651	8948×10^{-6}	2598	9319×10^{-5}	7453×10^{-5}
3a	1514	2612×10^{-5}	1445	2090	8851	1501×10^{-4}	1432	1318×10^{-4}	1813×10^{-4}	1331×10^{-4}	3324×10^{-5}	1756	2955	1561
2a	1306	2051	1150	1792	5178	1018	8237×10^{-5}	1251	1579	2468	9381	2809	3454	1477
1a	7226×10^{-6}	1150	6551×10^{-6}	1322	3190	5920×10^{-5}	8397×10^{-5}	2297	4191×10^{-5}	1419	4723×10^{-4}	7050	2809	8779×10^{-6}
							$\alpha = 0.6$							
1	2726×10^{-5}	5165×10^{-5}	3263×10^{-5}	3682×10^{-5}	1147×10^{-4}	1527×10^{-4}	1180×10^{-4}	1270×10^{-4}	1301×10^{-4}	8147×10^{-5}	2722×10^{-5}	2788×10^{-5}	4654×10^{-5}	2656×10^{-5}
2	2583	5896	4892	8453	2000	1336	7872×10^{-5}	1117	9417×10^{-5}	5407	2500	2333	3790	2327
3	1631	4892	1149×10^{-4}	3786×10^{-4}	1217	4331×10^{-5}	2942	7677 x 10^{-5}	5961	3750	2060	1519	2333	1394
5	2083	9564	4284	1070	4772×10^{-5}	2573	1913	4155	5354	5093	4258	2330	2829	1540
6	6486	2263×10^{-4}	1376	4772×10^{-5}	5015	4033	3151	5570	7726	6798	5093	4243	6118	4608
7	8640	1512	4899×10^{-5}	2573	4033	4207	3923	8484	1032×10^{-4}	7726	5354	6744	1065×10^{-4}	7361
8	6677	8906×10^{-5}	3328	1913	3151	3923	5036	2035×10^{-4}	8484×10^{-5}	5570	4155	8686	1264	7182
8a	1540	2829	2330	4298	5093	5354	4155	1913×10^{-5}	2573	4772	1070×10^{-4}	4281×10^{-4}	9564×10^{-5}	2083
7a	4608	6118	4243	5093	6798	7726	5570	3151	4033	5015	4772×10^{-5}	1376	2263×10^{-4}	6486
6a	7361	1065×10^{-4}	6744	5354	7726	1032×10^{-4}	8484	3923	4207	4033	2573	4899×10^{-5}	1512	8640
5a	7182	1264	8686	4155	5570	8484×10^{-5}	2035×10^{-4}	5036	3923	3151	1913	3328	8906×10^{-5}	6677
3a	2656	4654×10^{-5}	2788	2722	8147	1301×10^{-4}	1270	1180×10^{-4}	1527×10^{-4}	1147×10^{-4}	3682	3263	5165	2726
2a	2327	3790	2333	2500	5407	9417×10^{-5}	1117	7872×10^{-5}	1536	2000	8453	4892	5896	2583
1a	1394	2333	1519	2060	3750	5961	7677 x 10^{-5}	2942	4331×10^{-5}	1217	3786×10^{-4}	1149×10^{-4}	4892	1631
							$\alpha = 0.4$							
1	3550×10^{-5}	6771×10^{-5}	4726×10^{-5}	4424×10^{-5}	9928×10^{-5}	1261×10^{-4}	1046×10^{-4}	1108×10^{-4}	1115×10^{-4}	7703×10^{-5}	3710×10^{-5}	4219×10^{-5}	6254×10^{-5}	3480×10^{-5}
2	3386	7494	6469	7923	1567×10^{-4}	1121	7636 x 10^{-5}	9937×10^{-5}	8748×10^{-5}	5835	3503	3719	5346	3127
3	2363	6469	1353×10^{-4}	2882×10^{-4}	1053	4850×10^{-5}	3872	7277	6191	4498	3027	2757	3719	2109
5	2503	8964	3261	1254	6197×10^{-5}	3843	3174	5123	5803	5318	4451	3424	3964	2099
6	5616	1773×10^{-4}	1191	6197×10^{-5}	6410	5422	4563	6290	7695	6809	5318	5089	6602	4357
7	7133	1269	5487×10^{-5}	3843	5422	5652	5392	8207	9508	7695	5803	7005	9897	6309
8	5913	8640×10^{-5}	4381	3174	4563	5392	6512	1607×10^{-4}	8207	6290	5123	8233	1124×10^{-4}	6266
8a	2099	3964	3424	4451	5318	5803	5123	3174×10^{-5}	3843	6197	1254	3261×10^{-4}	8963×10^{-5}	2503
7a	4357	6602	5089	5318	6809	7695	6290	4563	5422	6410	6197×10^{-5}	1191	1773×10^{-4}	5616
6a	6309	9897	7005	5803	7695	9508	8207	5392	5652	5422	3843	5487×10^{-5}	1269	7133
5a	6266	1124×10^{-4}	8233	5123	6290	8207	1607×10^{-4}	6512	5392	4563	3174	4381	8640×10^{-5}	5915
3a	3480	6254×10^{-5}	4219	3710	7703	1115×10^{-4}	1108	1046×10^{-4}	1261×10^{-4}	9928	4424	4726	6771	3550
2a	3127	5346	3719	3503	5835	8748×10^{-5}	9937×10^{-5}	7636 x 10^{-5}	1121	1567×10^{-4}	7923	6469	7494	3386
1a	2109	3719	2757	3027	4498	6191	7277	3872	4850×10^{-5}	1053	2882×10^{-4}	1353×10^{-4}	6469	2363
							$\alpha = 0.2$							
1	4041×10^{-5}	7826×10^{-5}	6329×10^{-5}	5593×10^{-5}	8585×10^{-5}	1001×10^{-4}	9017×10^{-5}	9347×10^{-5}	9310×10^{-5}	7448×10^{-5}	5160×10^{-5}	5947×10^{-5}	7471×10^{-5}	3993×10^{-5}
2	3913	8313	7631	7620	1152×10^{-4}	9239×10^{-5}	7473	8704	8088	6458	4979	5549	6814	3735
3	3164	7631	1287×10^{-4}	1916×10^{-4}	9129×10^{-5}	5792	5230	7164	6630	5580	4533	4720	5549	2973
5	3164	8621	2168	1179	7096	5339	4861	6149	6429	5958	5256	5128	5633	2919
6	4857	1303×10^{-4}	1021	7096 x 10^{-5}	7187	6503	5938	6888	7571	6956	5958	6313	7307	4213
7	5665	1045	6553×10^{-5}	5339	6503	6704	6548	7848	8531	7571	6429	7500	9151	5266
8	5101	8455×10^{-5}	5917	4861	5938	6548	7307	1178×10^{-4}	7848	6888	6149	8105	9847	5287
8a	2919	5633	5128	5256	5958	6429	6149	4861 x 10^{-5}	5339	7096	1179×10^{-4}	2168×10^{-4}	8621	3164
7a	4213	7307	6313	5958	6956	7571	6888	5938	6503	7187	7096 x 10^{-5}	1021	1303×10^{-4}	4857
6a	5266	9151	7500	6429	7571	8531	7848	6548	6704	6503	5339	6553×10^{-5}	1045	5665
5a	5287	9847	8105	6149	6888	7848	1178×10^{-4}	7307	6548	5938	4861	5917	8455	5101
3a	3993	7471	5947	5160	7448	9310	9347 x 10^{-5}	9017	1001×10^{-4}	8585	5593	6329	7826	4041
2a	3735	6814	5549	4979	6458	8088	8704	7473	9239 x 10^{-5}	1152×10^{-4}	7620	7631	8313	3913
1a	2973	5549	4720	4533	5580	6630	7164	5230	5792	9029×10^{-5}	1916×10^{-4}	1287×10^{-4}	7631	3164

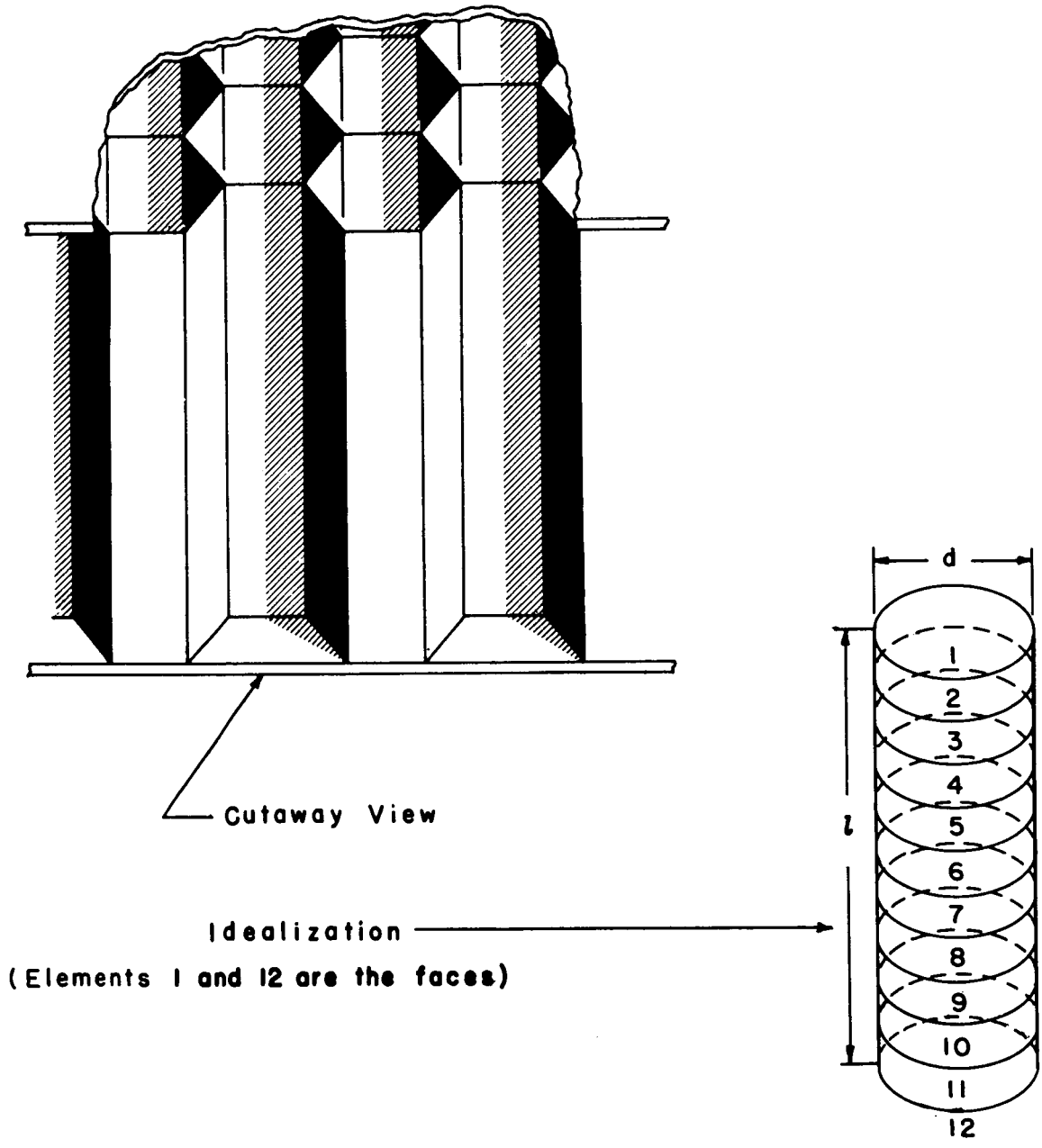

Figure 1.- Honeycomb-core panel and idealization used.

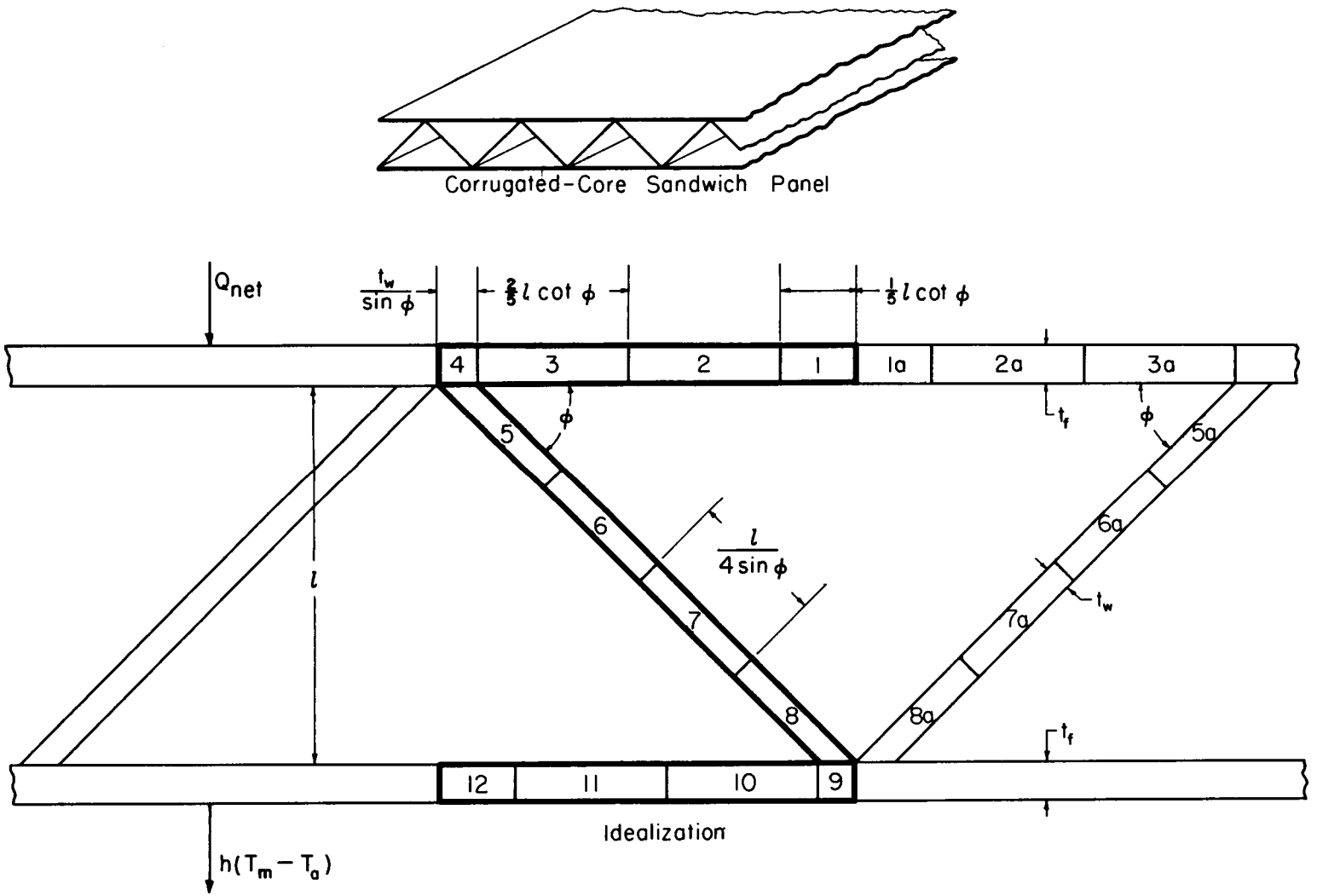

Figure 2.- Corrugated-core panel and idealization used.

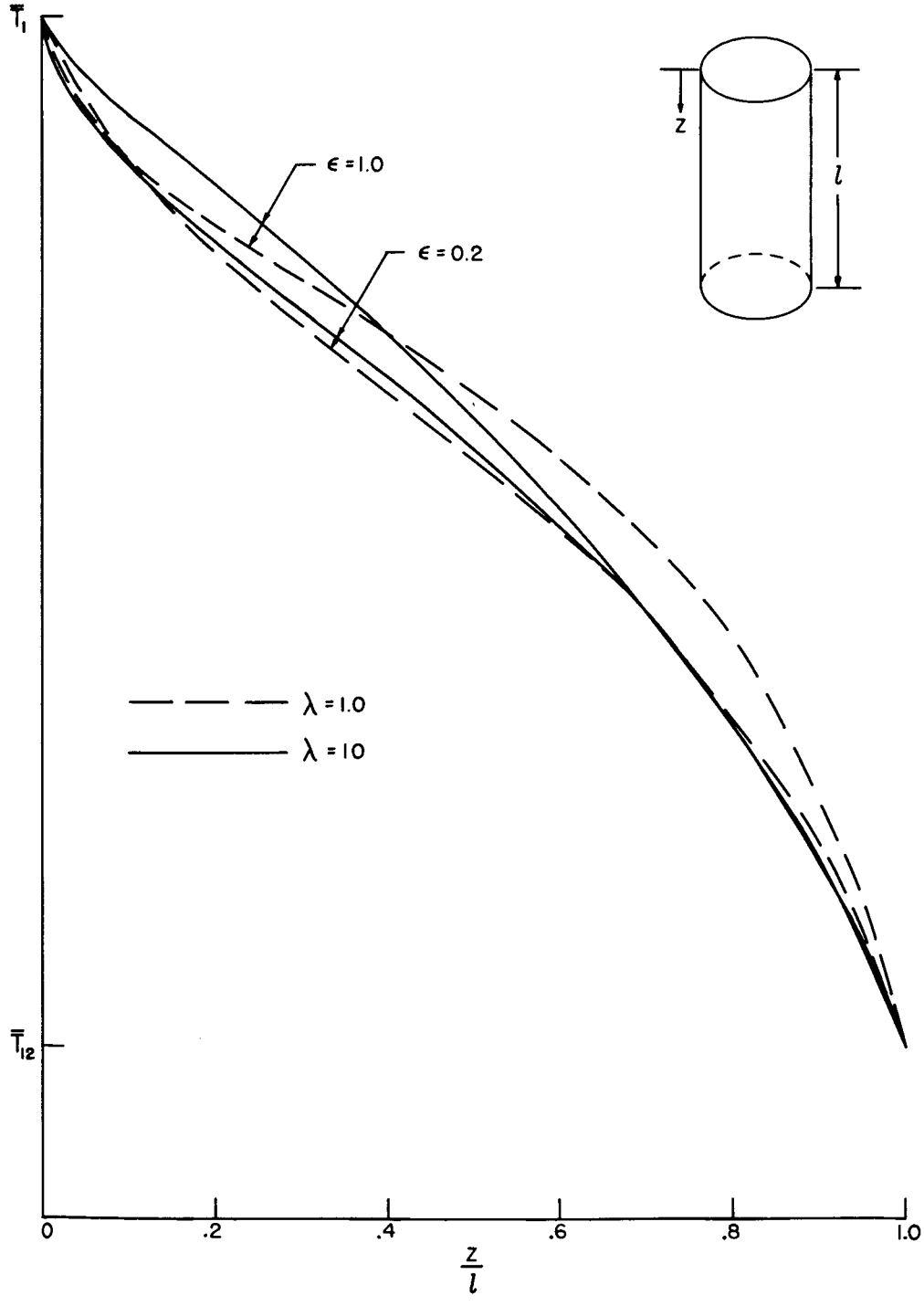

Figure 3.- Typical calculated temperature distribution for honeycomb-core panels.

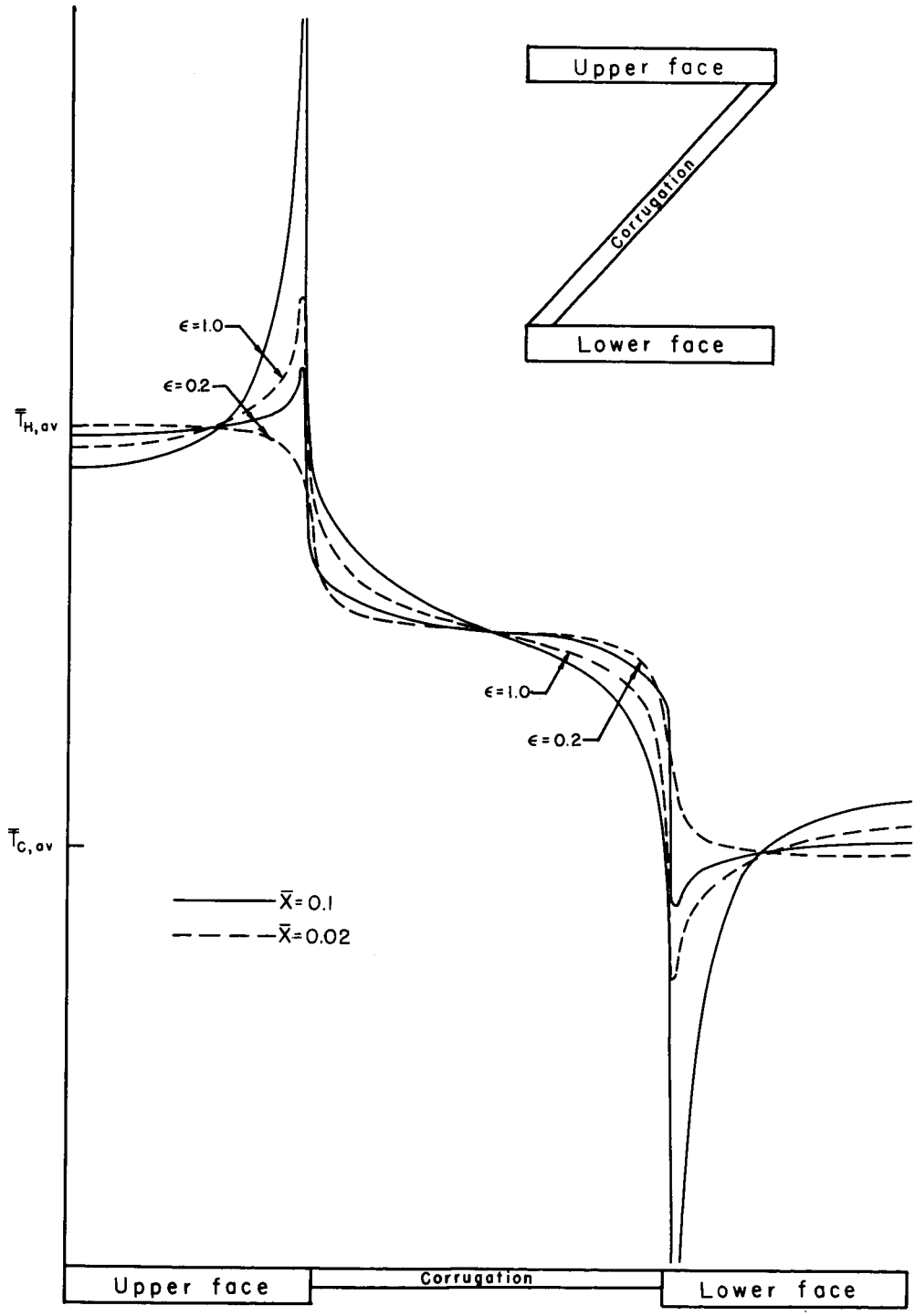

Figure 4.- Typical calculated temperature distributions for corrugated-core panels. $\bar{Y}$ = 0.5.

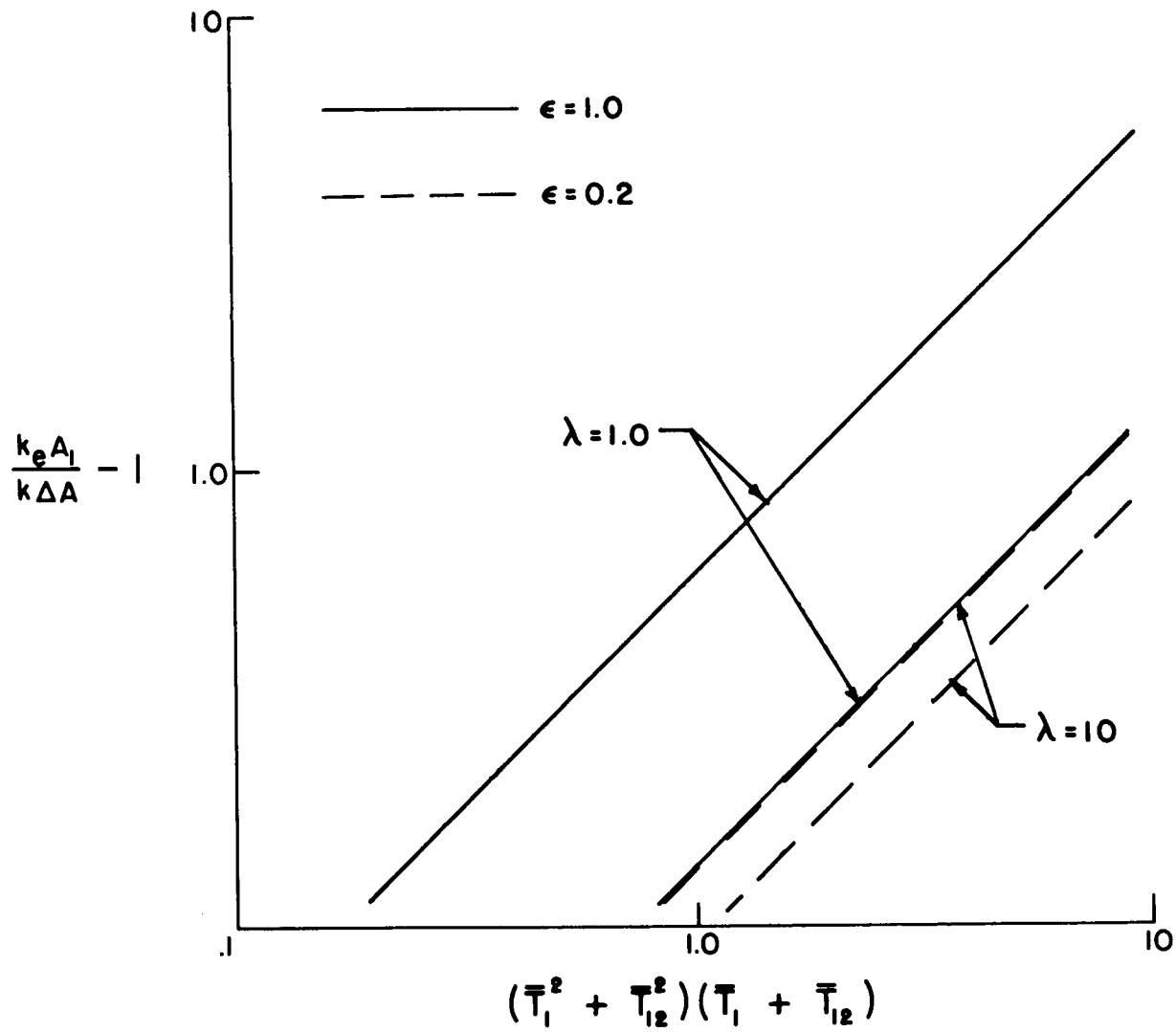

Figure 5.- Variation of effective conductivity ratio with λ and ϵ for honeycomb-core panels.

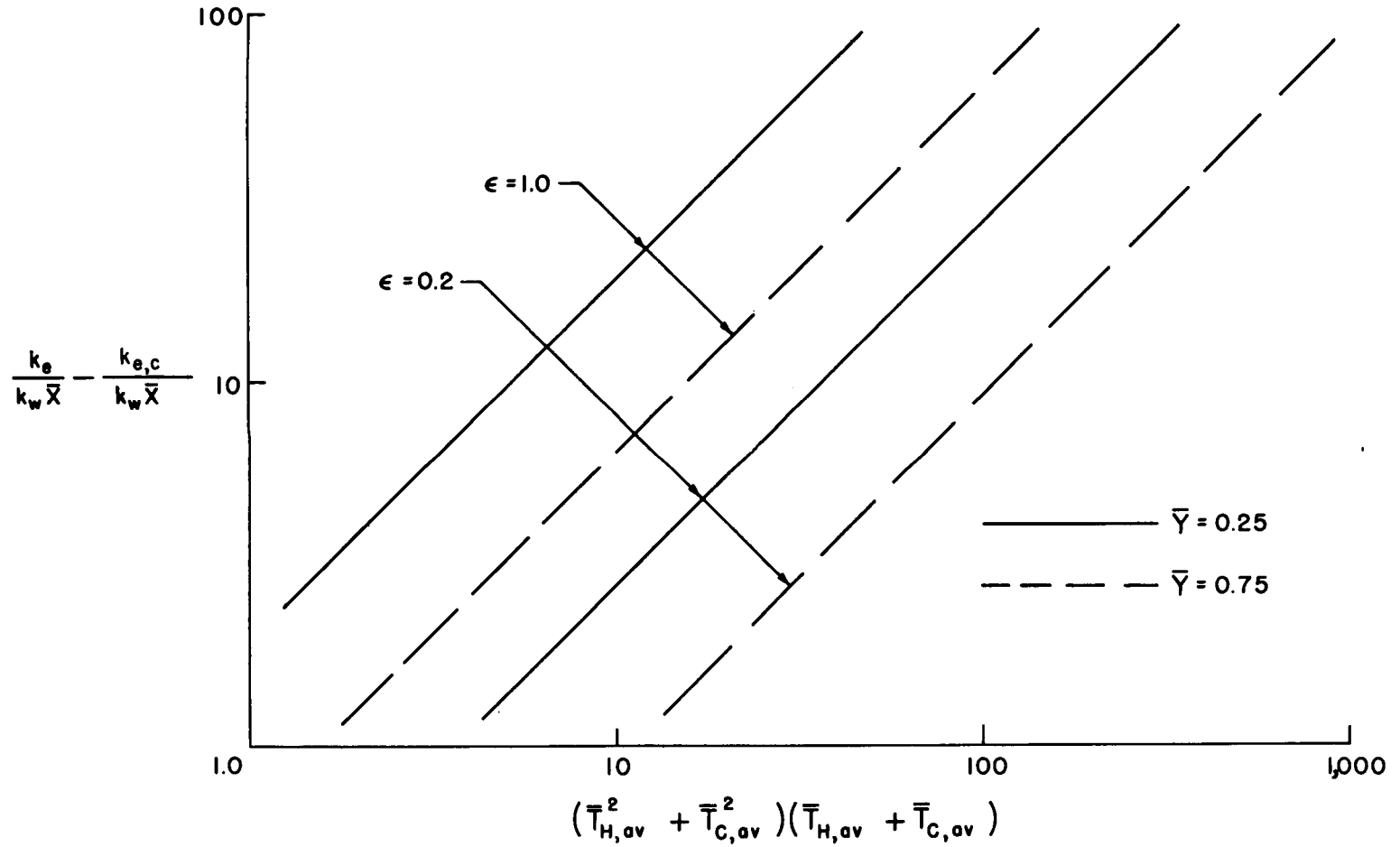

Figure 6.- Variation of effective conductivity ratio with $\bar{Y}$ and ϵ for corrugated-core panels. $\bar{X}$ = 0.05.

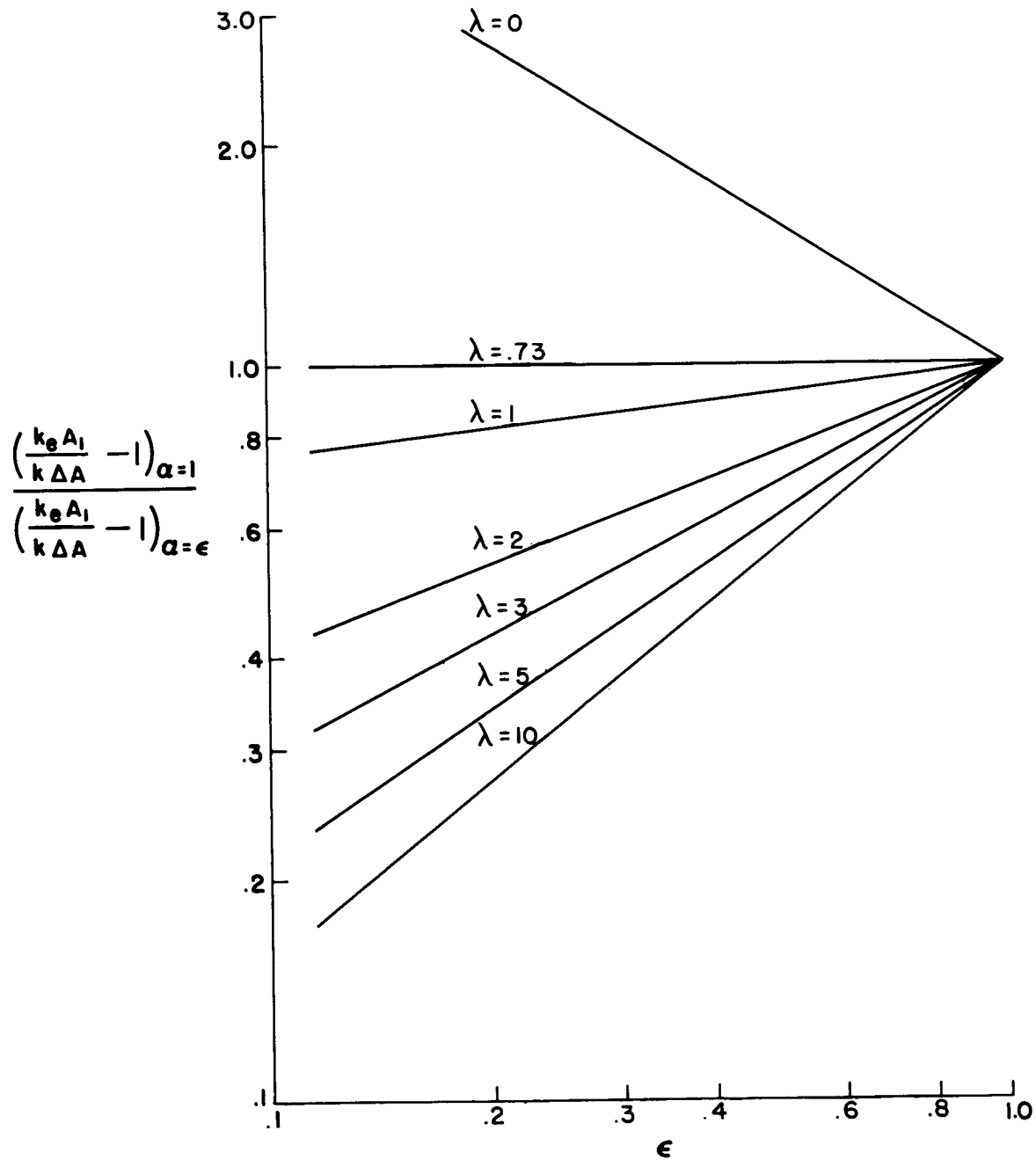

Figure 7.- Comparison of reflection and no-reflection analyses for honeycomb-core panels.

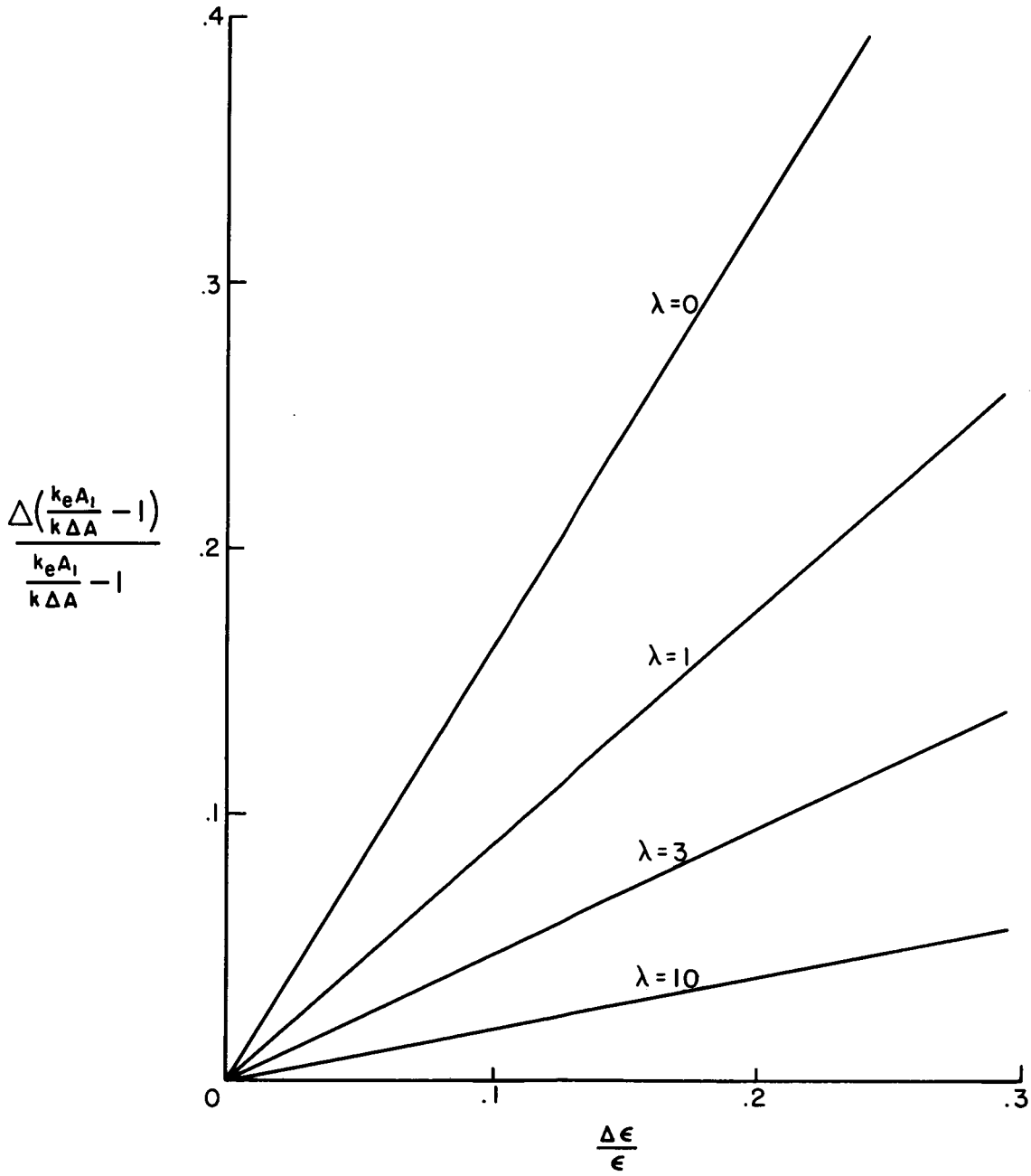

Figure 8.- Errors resulting from uncertainty in emissivity in honeycomb-core panels.

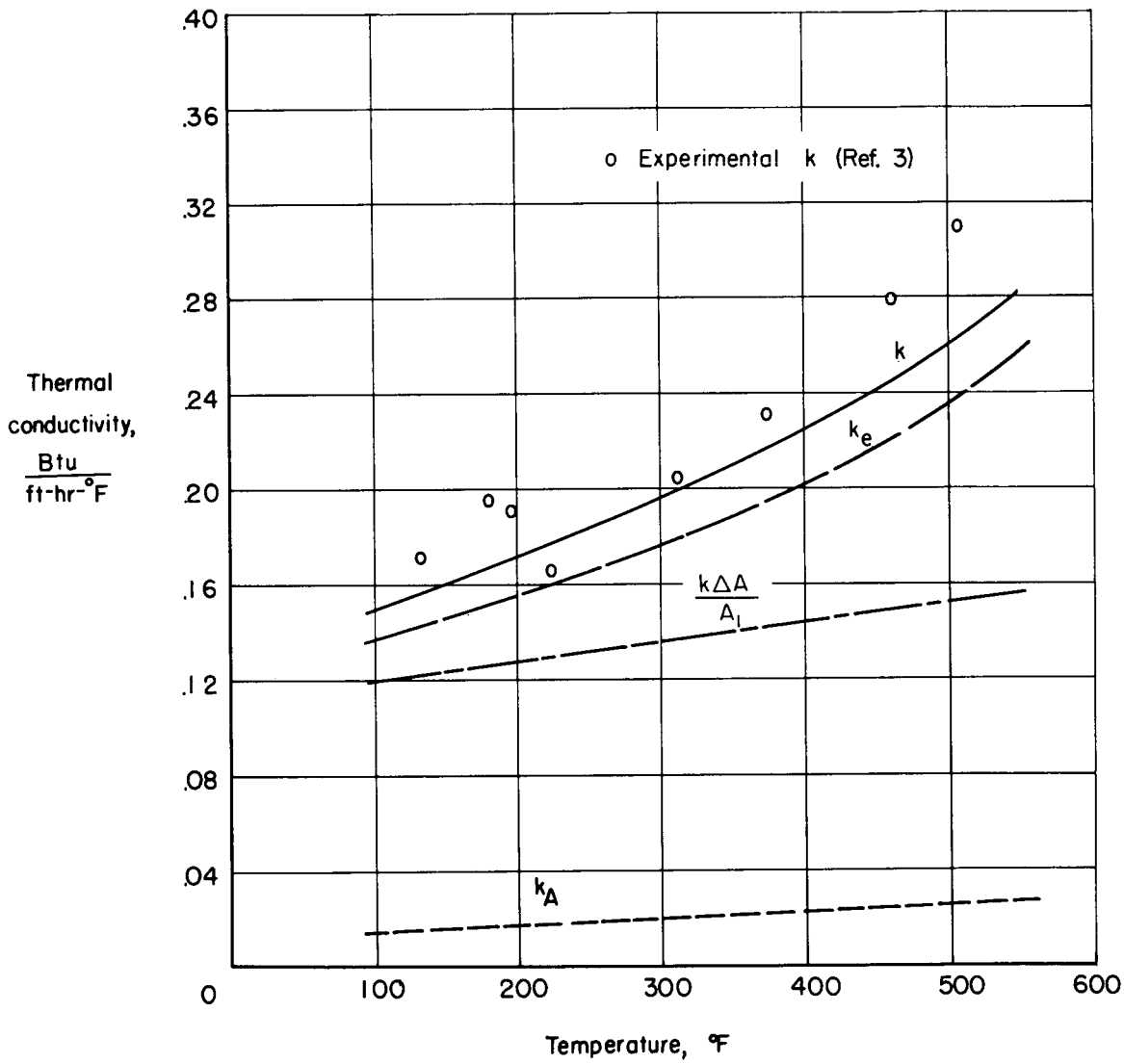

Figure 9.- Comparison of experimental and calculated results for honeycomb-core panels.